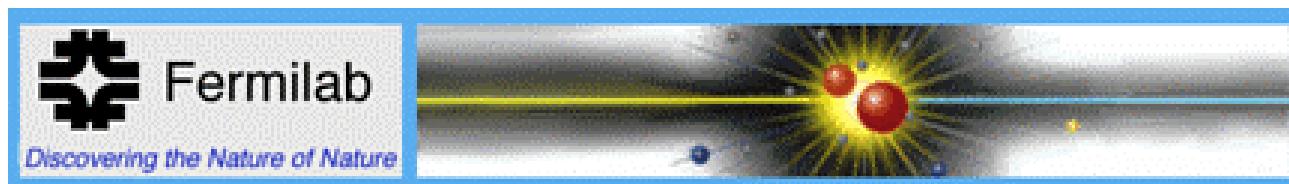


Recent Tevatron Results

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7th International Workshop on Deep Inelastic Scattering and QCD

March 19 - 23, 1999

Outline

- Jets
- Diffractive
- W/Z, Photon and Drell-Yan
- W mass
- CP violation

Data sets

Collider Experiments (CDF&D0)

pp at $\sqrt{s} = 1.8 \text{ TeV}$

- Run 1A (92-93) $\int Ldt \sim 15 \text{ pb}^{-1}$
- Run 1B (94-95) $\int Ldt \sim 90 \text{ pb}^{-1}$
- Run 1C (95-96) $\int Ldt \sim 15 \text{ pb}^{-1}$

Fixed Target Experiments

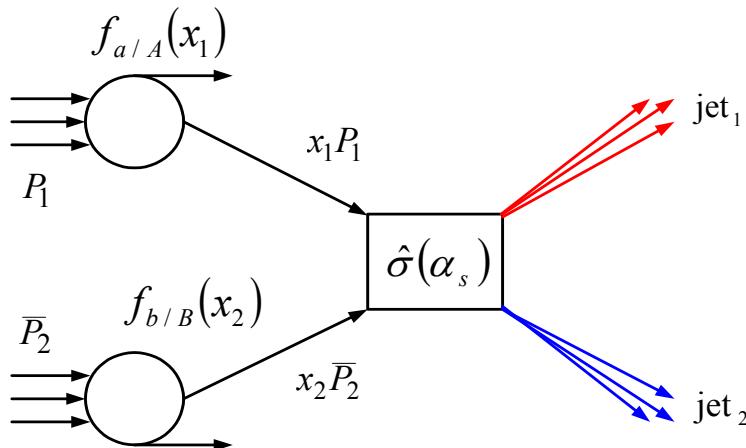
(KTeV, E706, E791)

(NuTeV covered in J. Morfin's talk)

p, π , γ beams

- 1996-1997 running period

QCD and Jet Production



- What is the value of α_s ?
- How well do we know the proton structure ? PDFs: $f(x)$
- Is NLO (α_s^3) sufficient?
- Are quarks composite structures?

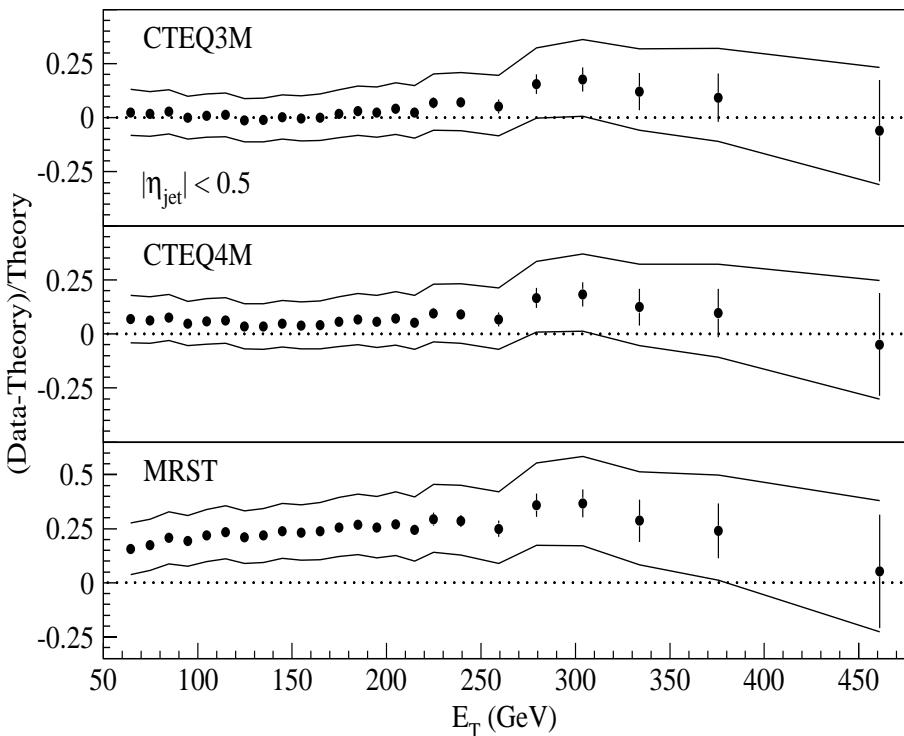
$$\sigma(p_1\bar{p}_2 \rightarrow 2 \text{ jets}) = \sum_{abcd} \int dx_1 dx_2 f_{a/A}(x_1) f_{b/B}(x_2) \hat{\sigma}(ab \rightarrow cd)$$

- Inclusive Jet Cross Section
(central region, η dependence, ratio of different cm energies)
 - Most simple test of NLO QCD
 - Extraction of α_s
 - PDFs at high Q^2
- Dijet Mass Spectrum
(x -section and ratio of different η regions)
 - Compositeness limit (Λ_c)
- Dijet Differential Cross Section
(η dependence)
 - PDFs extraction

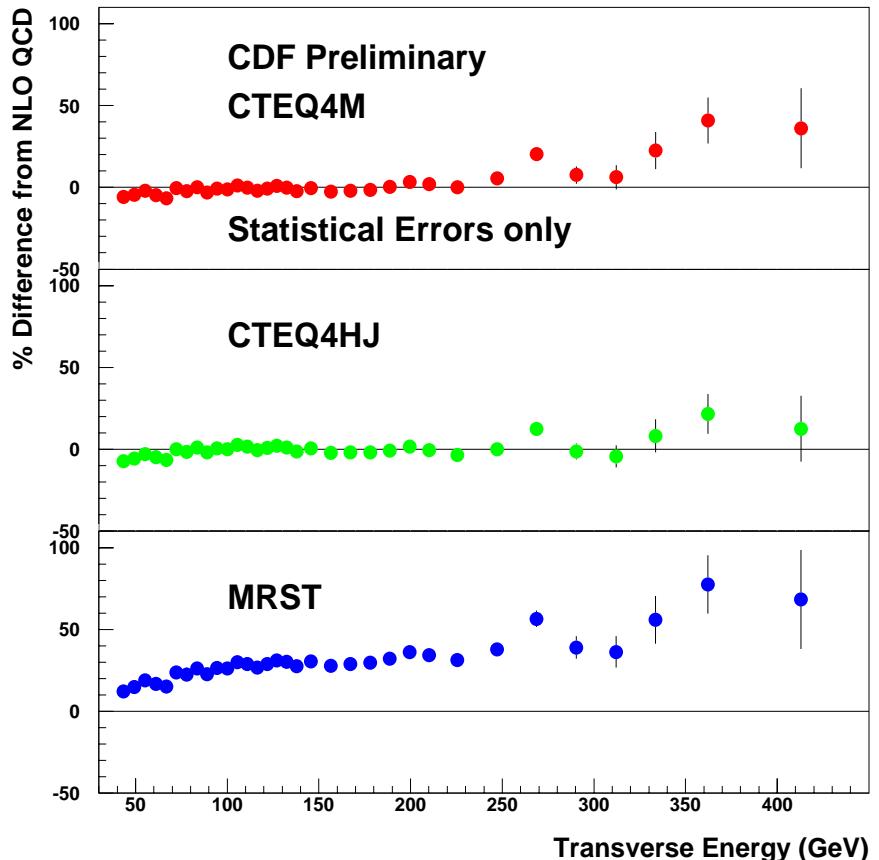
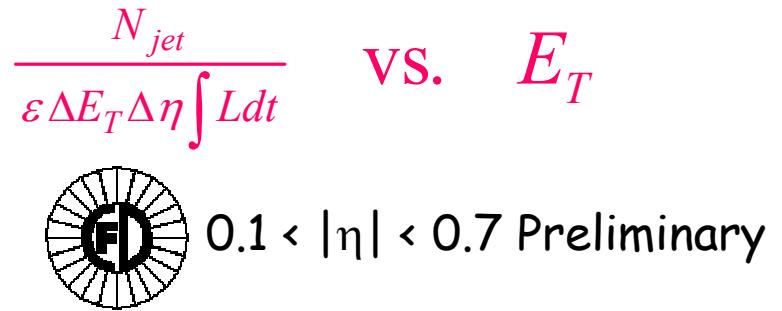
Inclusive Jet Cross Section



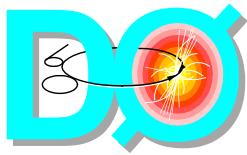
$|\eta| < 0.5$ PRL82, 2451 (1999)



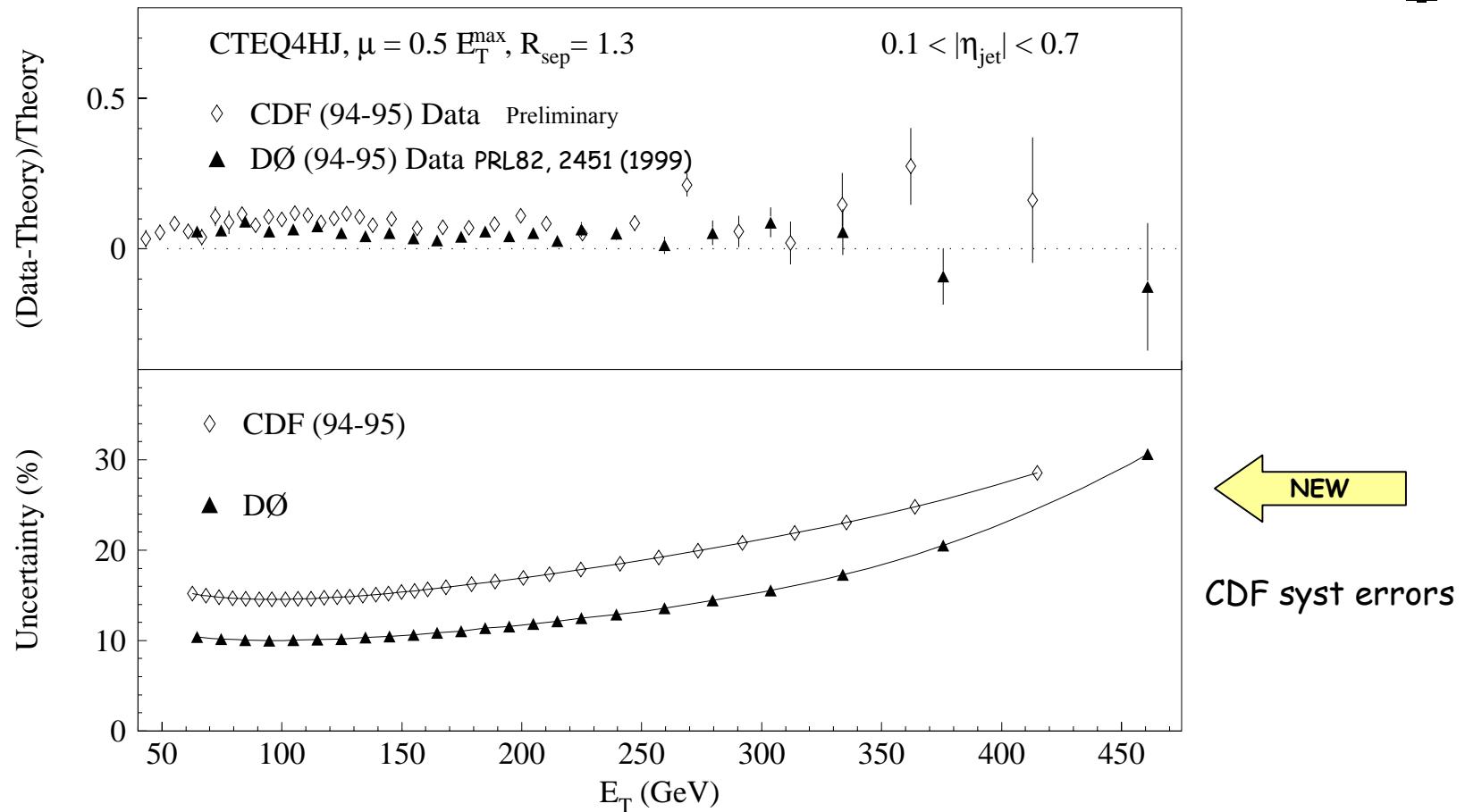
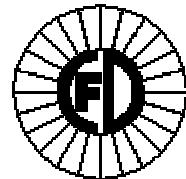
Data and theory agreement prob 47-90%



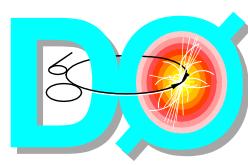
NLO QCD describes the data well



Inclusive Jet Cross Section at 1.8TeV



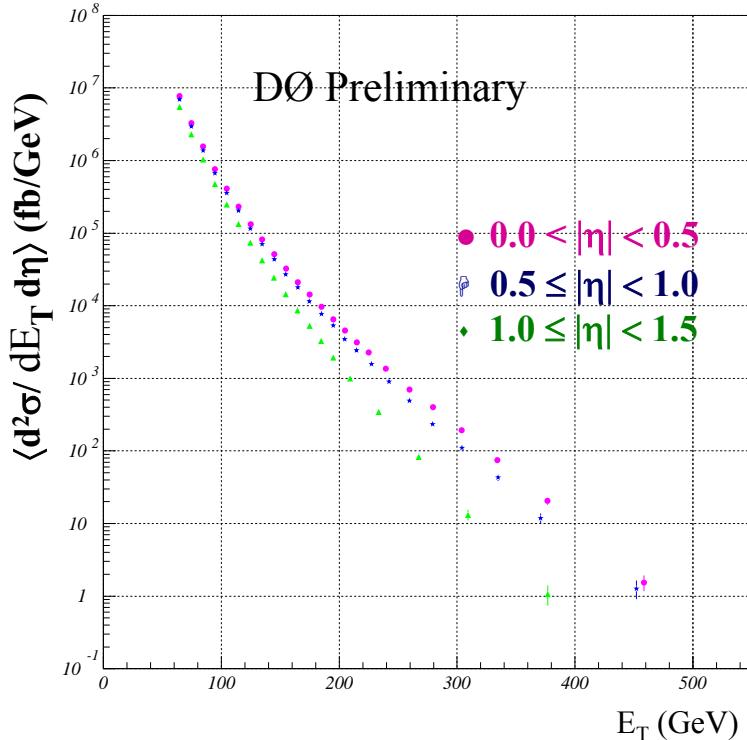
DØ and CDF data in good agreement. NLO QCD describes the data well.



Rapidity Dependence of the Inclusive Jet Cross Section



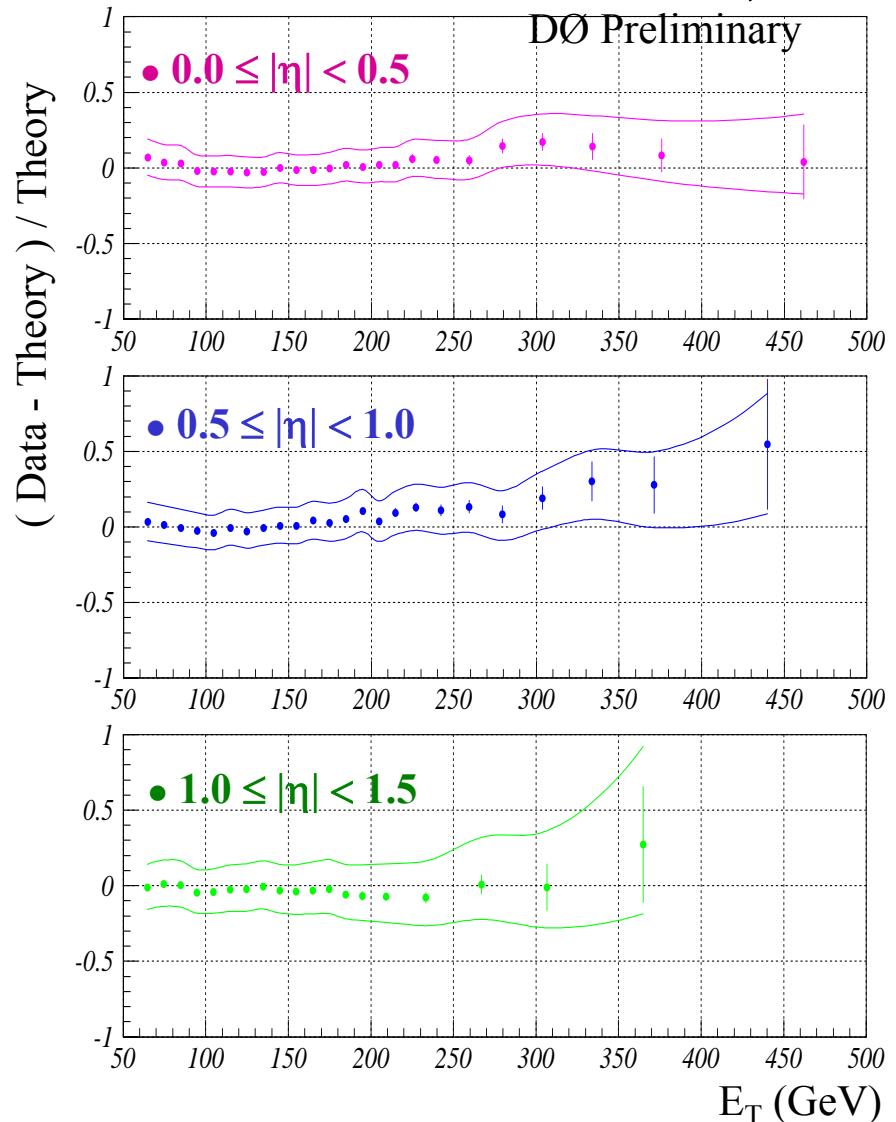
$\sqrt{s} = 1.8 \text{ TeV}, |\eta| < 1.5$



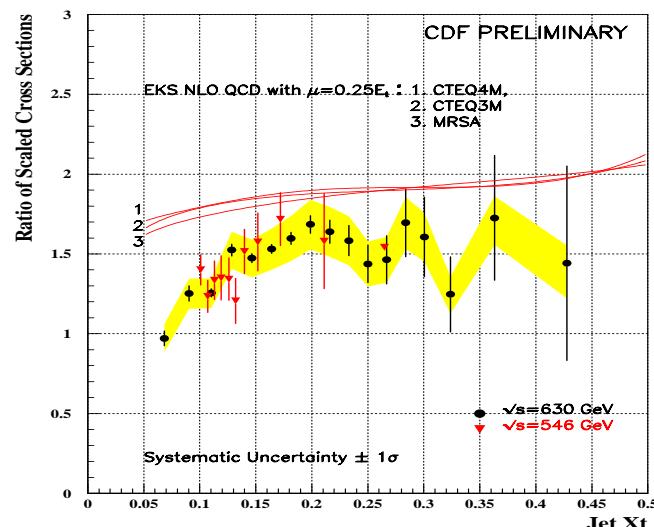
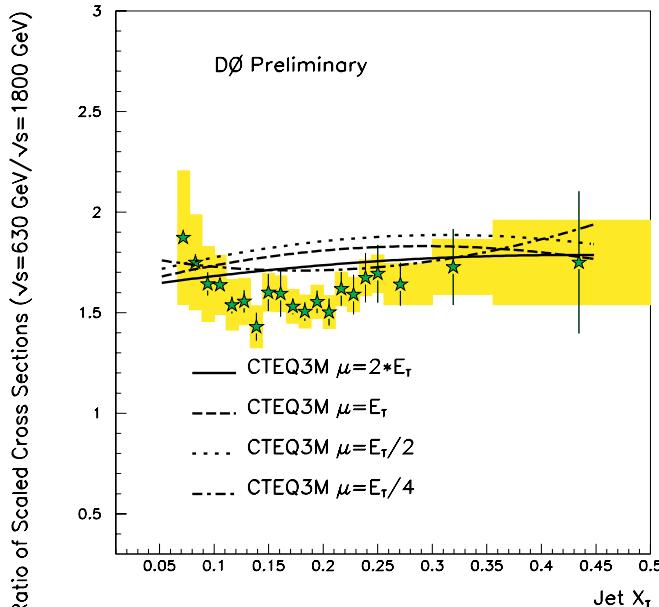
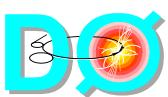
Data and NLO QCD in good agreement

Extend measurement to $|\eta| = 3$

Refine error analysis

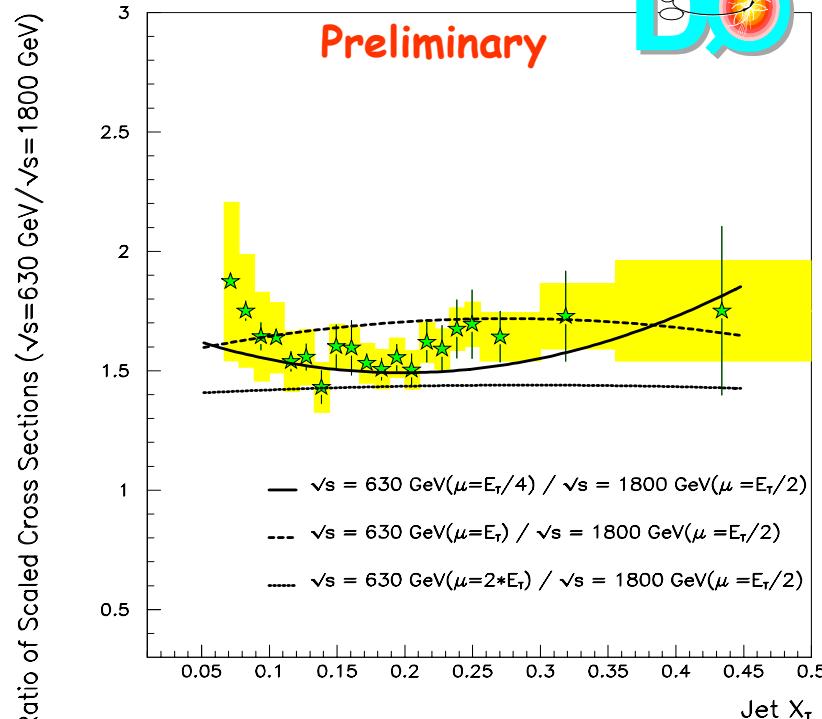


Ratio of Scale Invariant Cross Sections $\sigma_d(630)/\sigma_d(1800)$ vs x_T

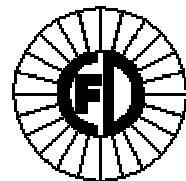


$$\sigma_d = (E_T^3/2\pi) (d^2\sigma/dE_T d\eta)$$

$$X_T = E_T / (\sqrt{s}/2)$$



- Taking different renormalization scales in theory for 630 vs 1800 GeV produces good quantitative agreement between D0 data and NLO QCD



Measurement of α_s from Inclusive Jet Production

NLO x-section can be parametrized as

$$\frac{d^2\sigma}{dE_T d\eta} = \alpha_s^2(\mu_R, \mu_F) A(E_T) + \alpha_s^3(\mu_R, \mu_F) B(E_T)$$

$\mu_R = \mu_F = \frac{E_T}{2}$

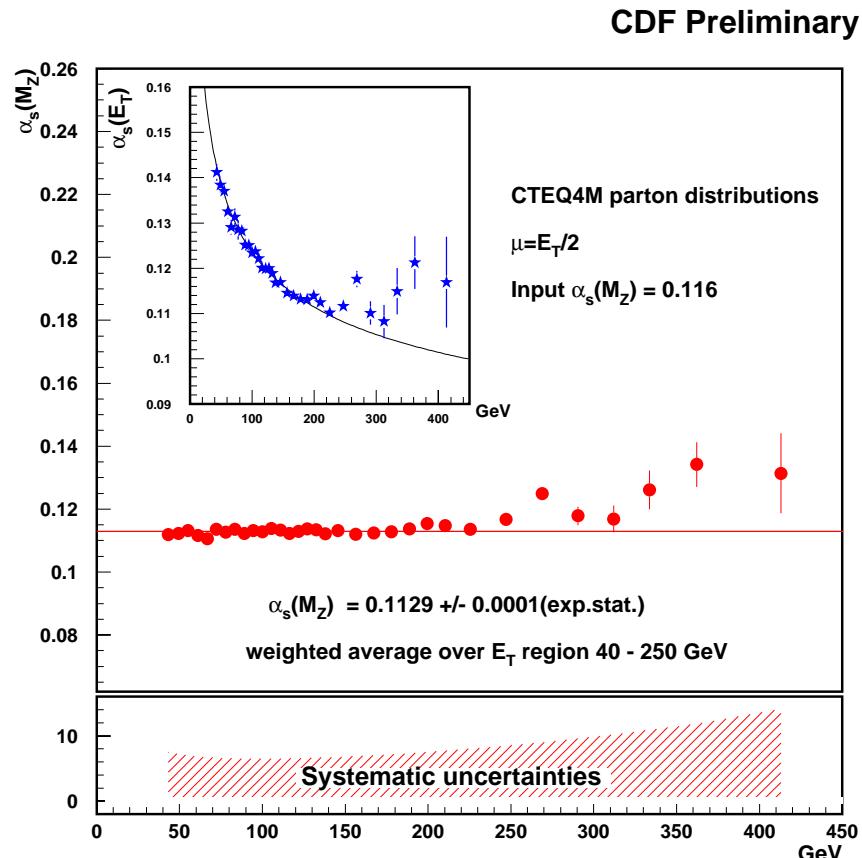
Measured by CDF

Obtained from JETRAD

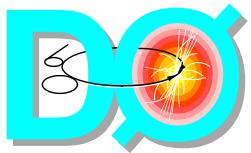
- Fitting the NLO prediction to the data determines $\alpha_s(E_T)$
- $\alpha_s(E_T)$ is evolved to $\alpha_s(M_Z)$ using 2-loop renormalization group equation

$$\alpha_s(M_Z) = 0.1129 \pm 0.0001 \pm 0.0078 \quad 0.0089$$

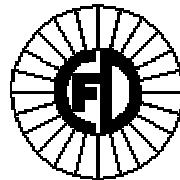
- Systematic uncertainties ($\sim 8\%$) from understanding of calorimeter response
- Measured value consistent with world average of $\alpha_s(M_Z) = 0.119 \pm 0.004$



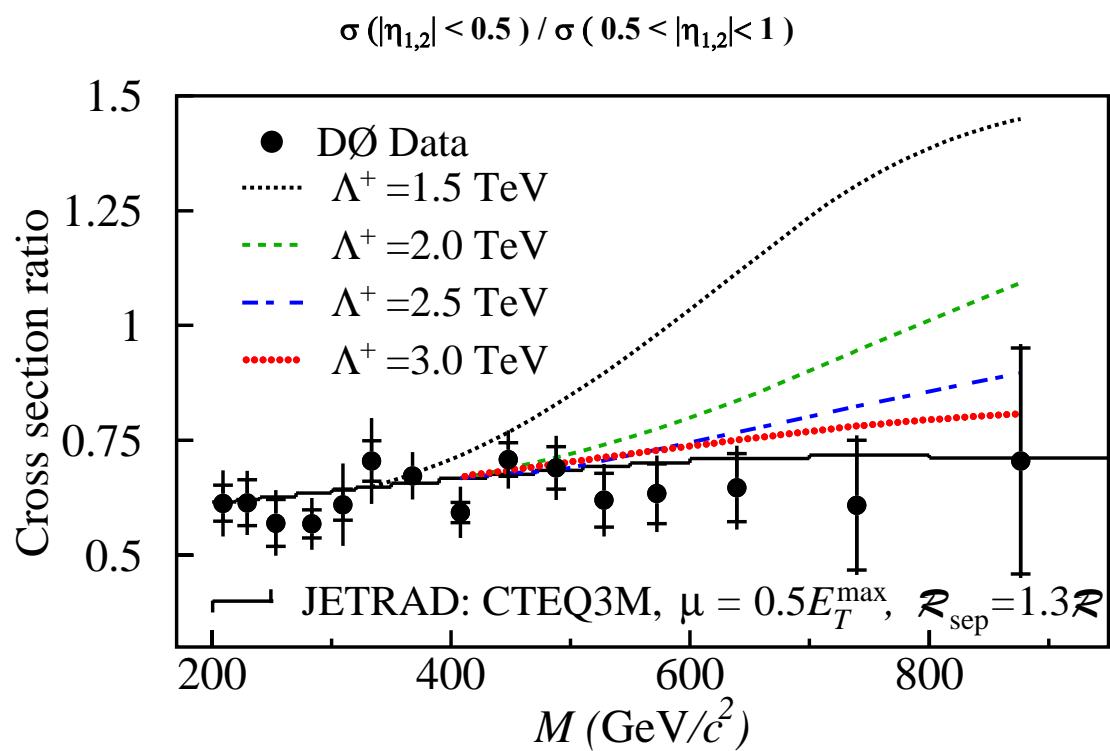
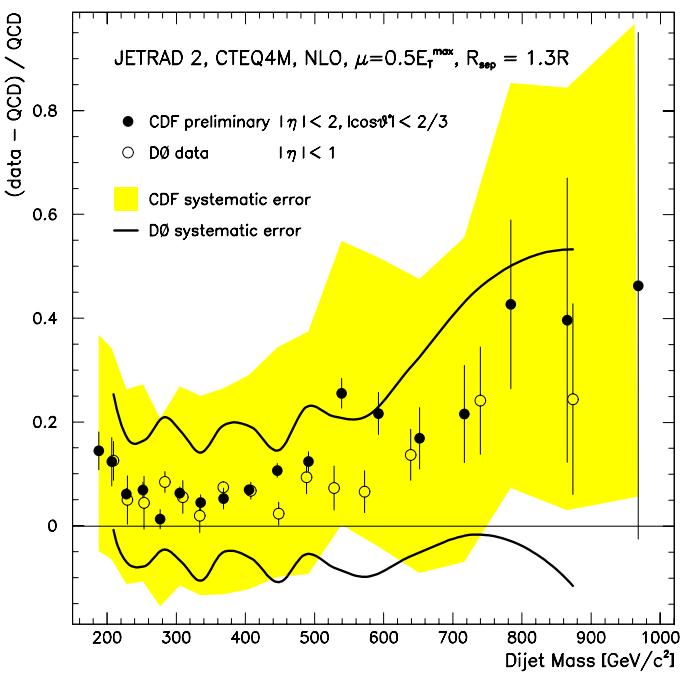
New measurement of α_s by a single experiment & from a single observable over a wide range of Q^2 .



Dijet Mass Cross Section

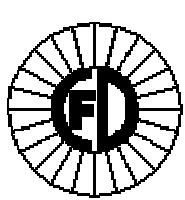


$$\frac{1}{\Delta M \Delta \eta_1 \Delta \eta_2} \int \int \int \frac{d^3 \sigma}{dM d\eta_1 d\eta_2} dM d\eta_1 d\eta_2 = \frac{N_{\text{events}}}{L \Delta M \Delta \eta_1 \Delta \eta_2}$$



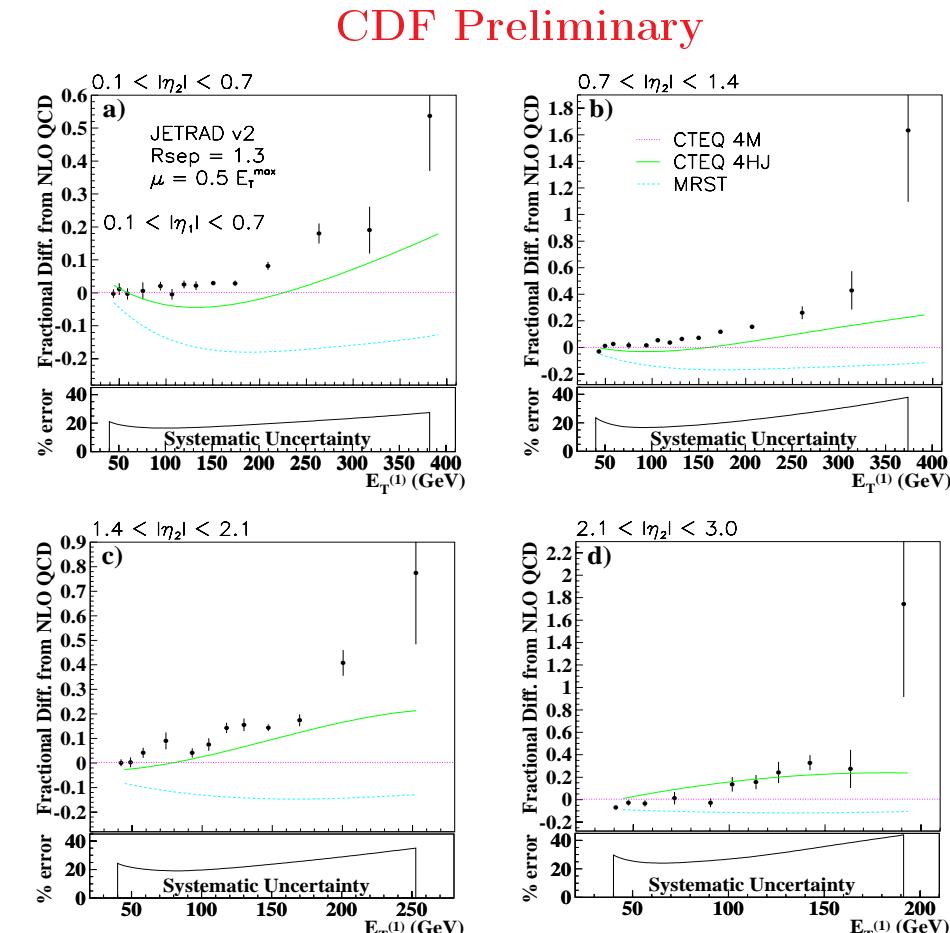
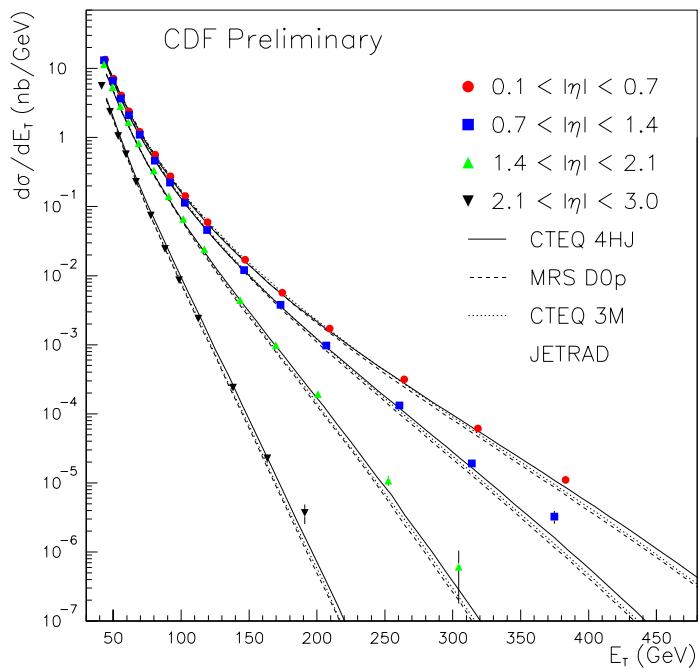
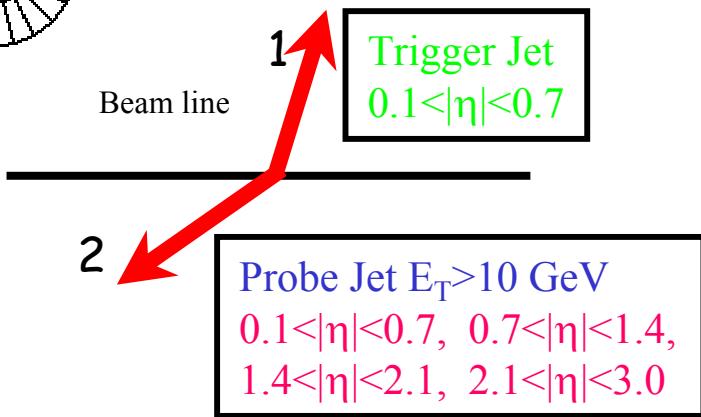
NLO QCD in good agreement with data

$\Lambda_c^+ > 2.7 \text{ TeV}$

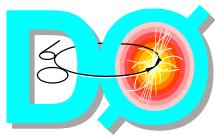


Inclusive Dijet Differential Cross Section

$$\frac{d^3\sigma}{dE_1^T d\eta_1 d\eta_2}$$

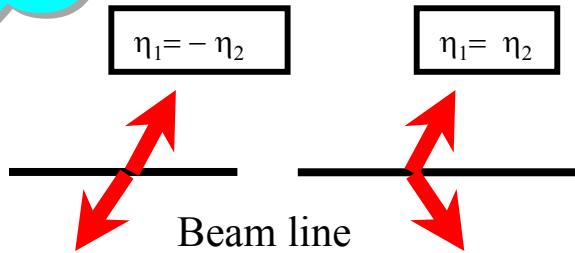


Distributions are sensitive to PDFs - CTEQ4HJ shows better agreement with data at high E_T



Inclusive Dijet Differential Cross Section

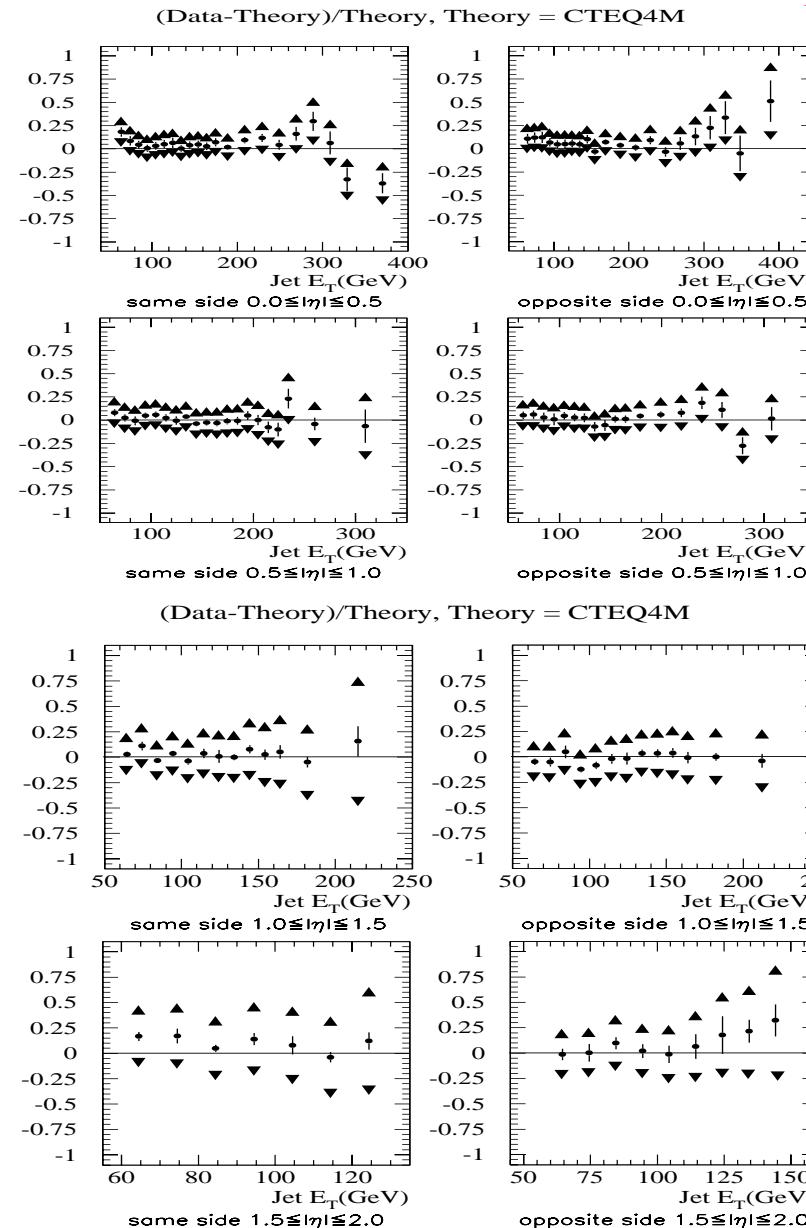
$$\frac{d^3\sigma}{dE_{1,2}^T d\eta_1 d\eta_2}$$

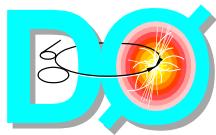


- Consider 4 η ranges:
 $0.0 < |\eta| < 0.5, 0.5 < |\eta| < 1.0, 1.0 < |\eta| < 1.5, 1.5 < |\eta| < 2.0$
- Divide data into two samples
- Measure E_T of both jets

\Rightarrow Total of 8 x-sections

DO data agree with NLO QCD
with CTEQ family PDFs within
the systematic uncertainty.



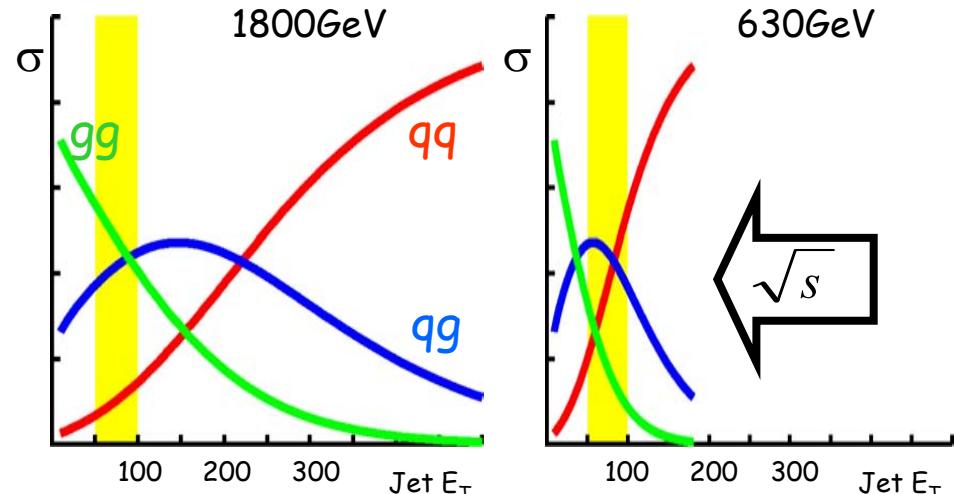


Subjet Multiplicity in Quark & Gluon Jets



Motivation:

- Separate q jets from g jets (top, Higgs, $W+Jets$ events)
- Test SU(3) dynamics (QCD color factors)
- ⇒ Measure the subjet multiplicity in quark and gluon jets

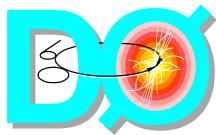


Method:

- Select quark enriched & gluon enriched jet sample and compare jet properties
- ① challenge is not to bias the samples.

Contributions of different initial states to the cross section for fixed Jet E_T vary with \sqrt{s}

① compare jets at same (E_T, η) produced at different \sqrt{s} & assume relative q/g content is known.



Subjet Multiplicity in Quark & Gluon Jets



$\sqrt{s} = 1800 \text{ GeV}$

Preliminary

Method:

- Subjet Multiplicity $M = f_g M_g + (1-f_g) M_q$
(g jet fractions f_g obtained from theory)

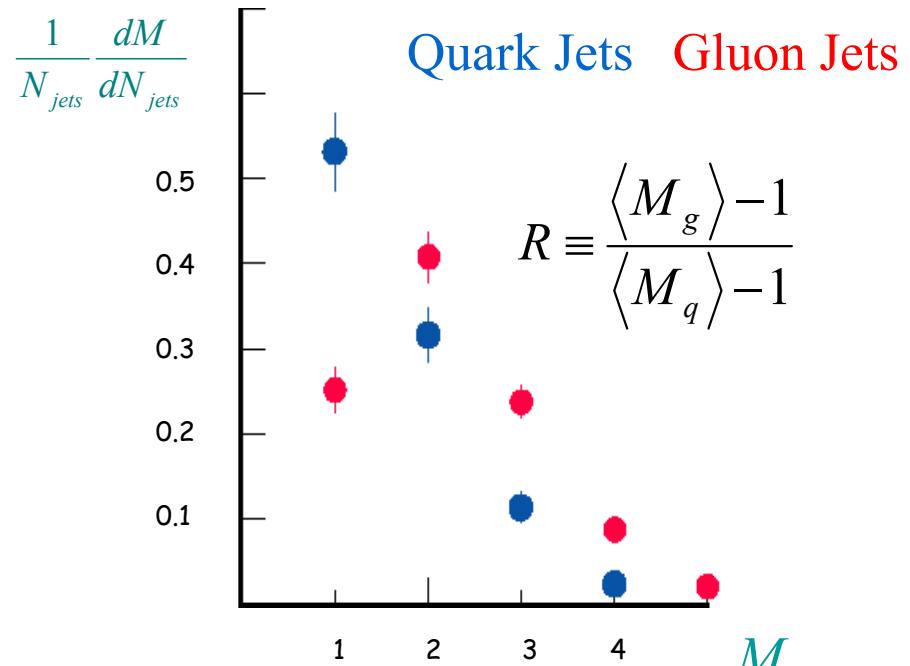
$$f^{630} = 33\% \quad f^{1800} = 59\%$$

- Assuming that the subjet multiplicity is independent of \sqrt{s} (verified with MC)

$$M_q = \frac{f^{1800} M^{630} - f^{630} M^{1800}}{f^{1800} - f^{630}}$$

$$M_g = \frac{(1-f^{630}) M^{1800} - (1-f^{1800}) M^{630}}{f^{1800} - f^{630}}$$

- Use k_T algorithm; unravel jets until all subjets are separated by $y_{cut} = .001$
- Measure number of subjets for events with jets with $55 < E_T < 100 \text{ GeV}$

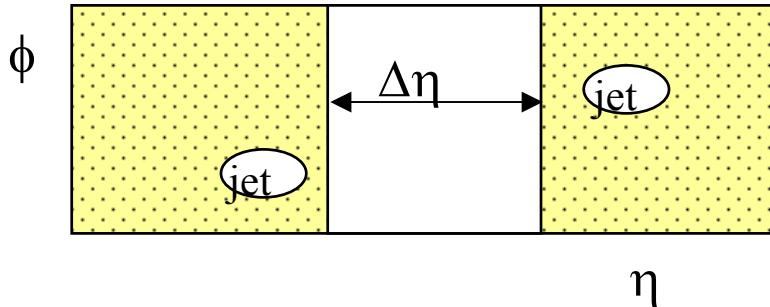
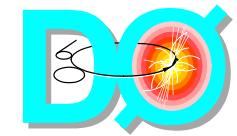


$$R = 1.91 \pm 0.04 \text{ (stat)} \pm \begin{matrix} 0.23 \\ 0.19 \end{matrix} \text{ (sys)}$$

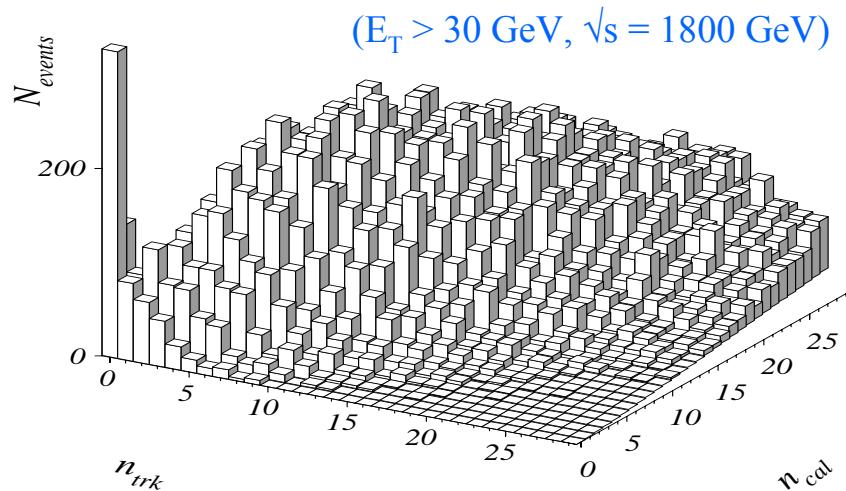
MC Prediction = $1.86 \pm 0.08 \text{ (stat)}$

Dominant uncertainties come from g jet fraction and choice of jet E_T

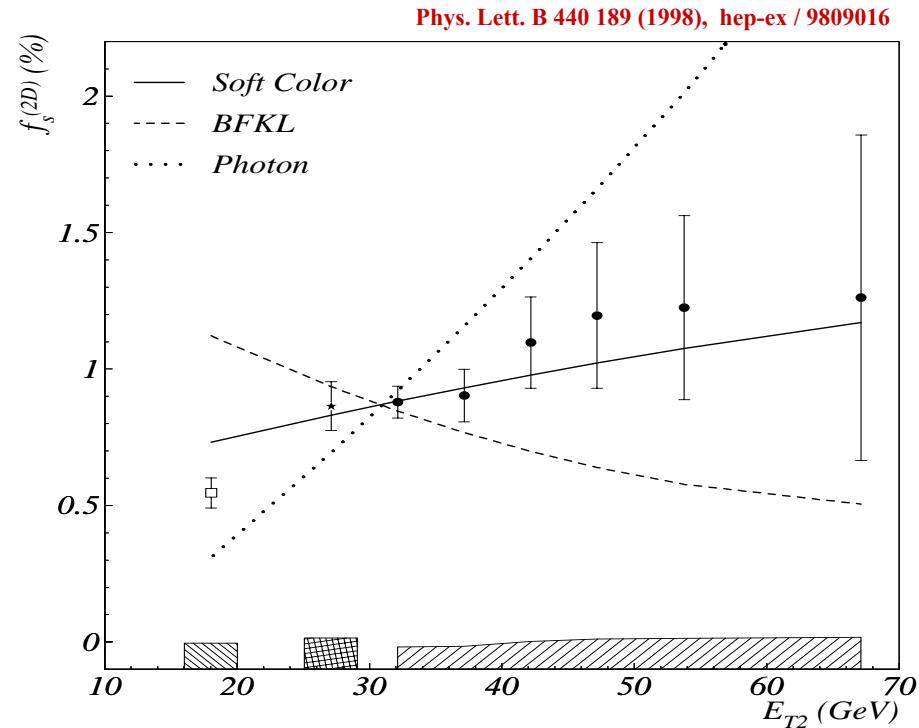
Hard Color-singlet Exchange Dijet Production



- Count tracks and EM Calorimeter Towers in $|\eta| < 1.0$ for events with two jets.



- Measured fraction of dijet events arising from color-singlet exchange is $.94 \pm .04(\text{stat}) \pm .12(\text{syst})\%$
- Too large to be explained by EW boson exchange
⇒ **indication of strong-interaction process.**

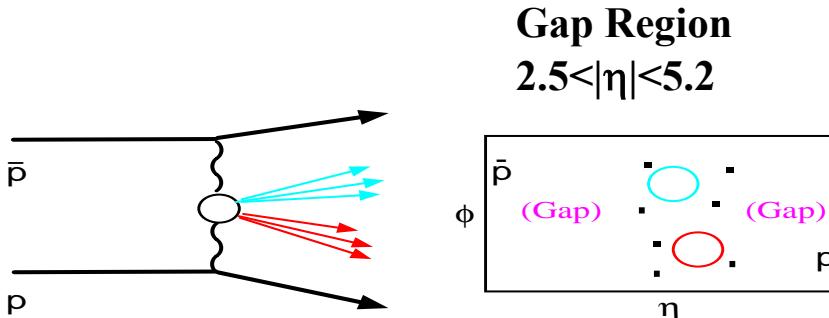


Fraction rises with parton x

Consistent with soft color rearrangement model preferring initial quark states
Inconsistent with BFKL two-gluon or massive photon/U(1) gauge boson models

Double Gaps at 1800 & 630 GeV

DØ Preliminary

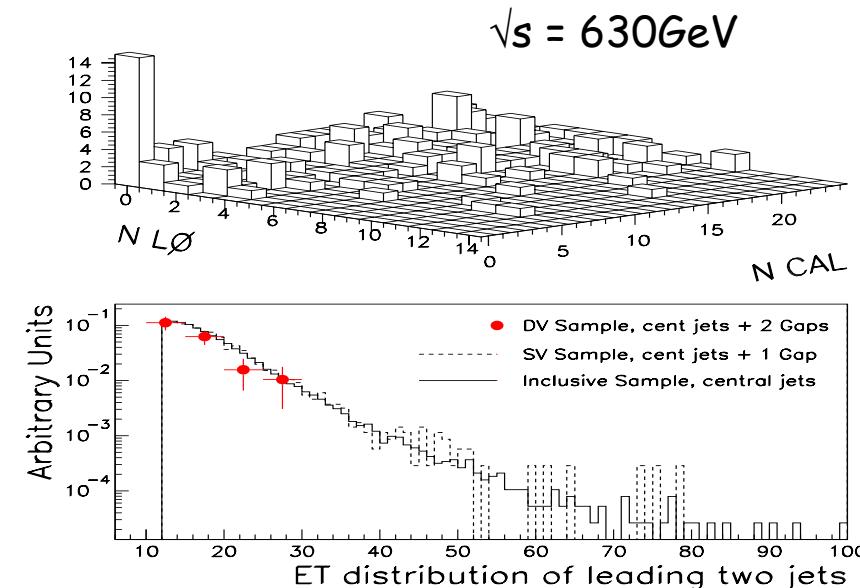
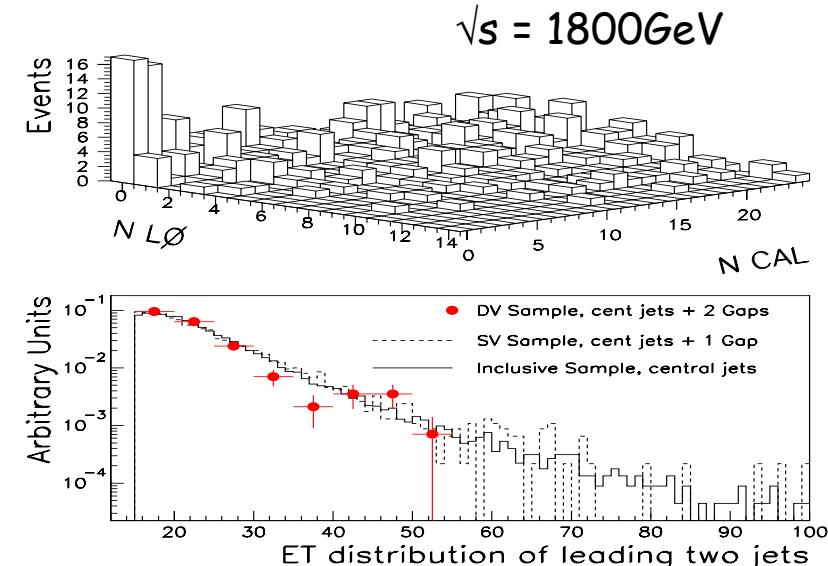


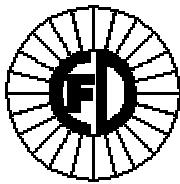
- Demand gap on one side, measure multiplicity on opposite side

➊ Observe an excess of double gap events

- Plot E_T distribution of the leading two jets for three data samples: Inclusive Two Jet sample with $|\eta_{\text{Jet}}| < 1.0$, One forward gap & Double Gap events

➋ E_T spectra of double-gap events is harder than expected if Pomeron carries $\approx 5\%$ of the proton's momentum



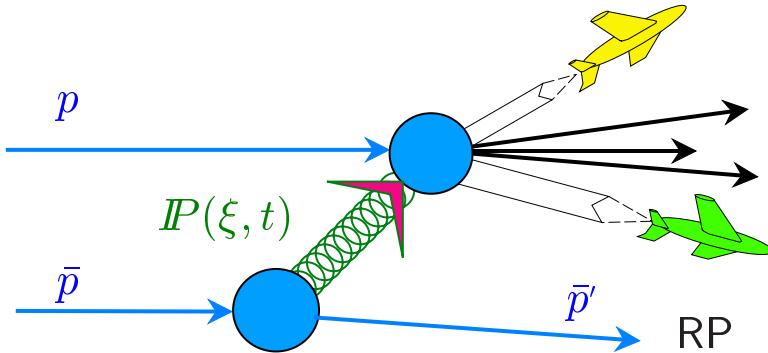


Diffractive Dijet Production

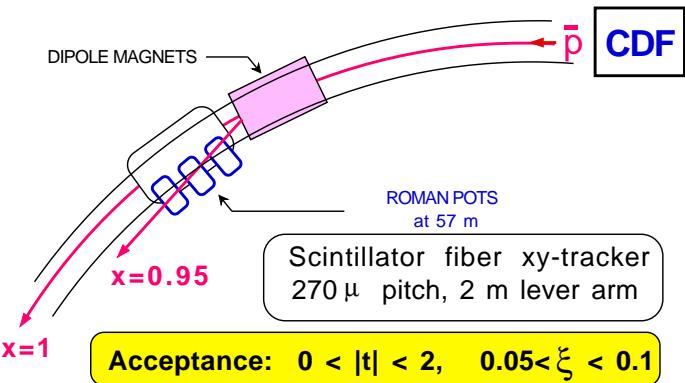
Dijets in Roman Pot Data

- Use roman-pot triggered data from Run 1C at 1800&630GeV
- Select events with two jets and roman pot hits
- Measure production rates and kinematic characteristics of diffractive dijet events

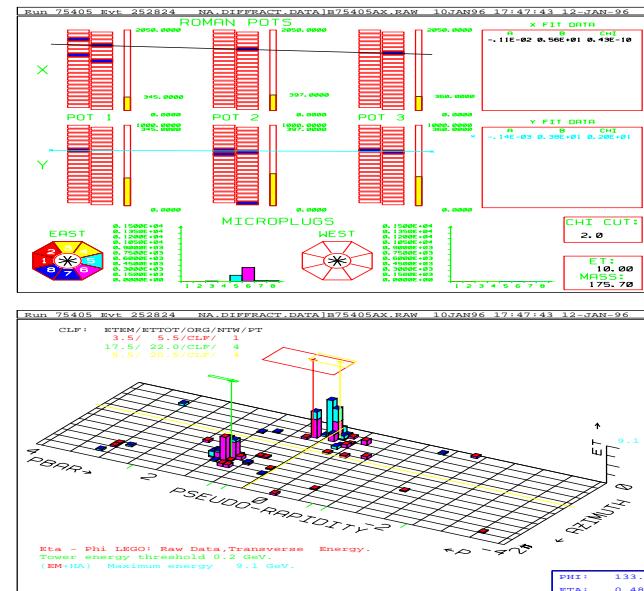
What are we looking for ?

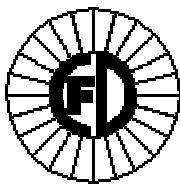


Roman Pots at CDF:



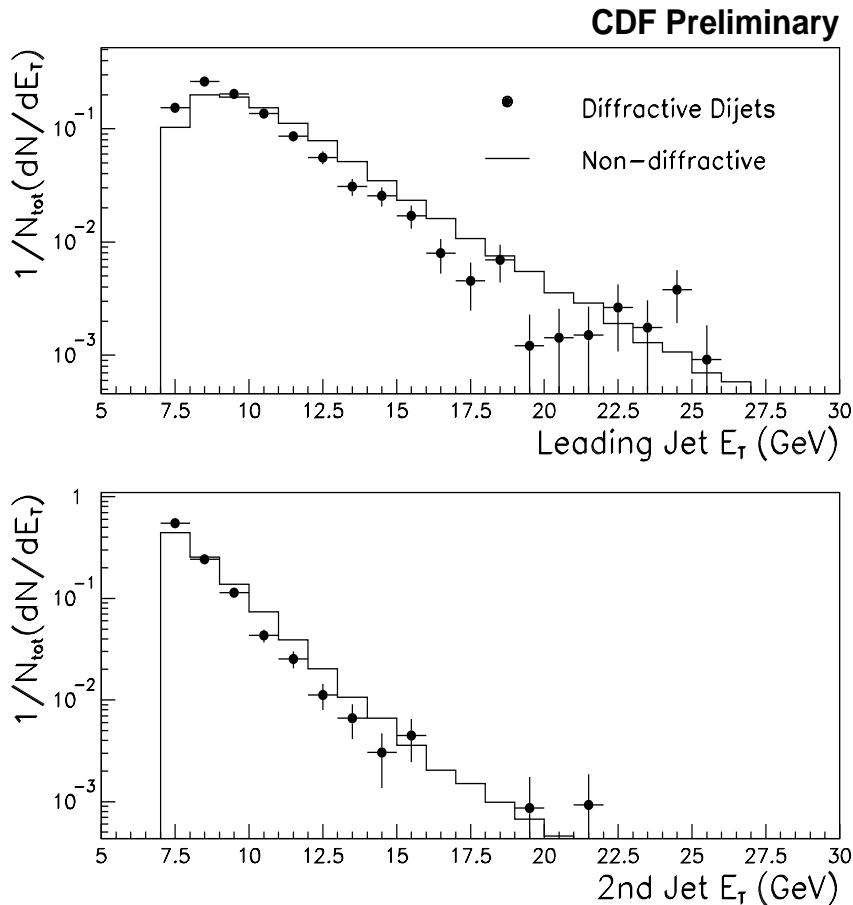
Dijet Event with Roman Pot Track:





Kinematic Characteristics of Diffractive Dijets

$\sqrt{s} = 630\text{GeV}$



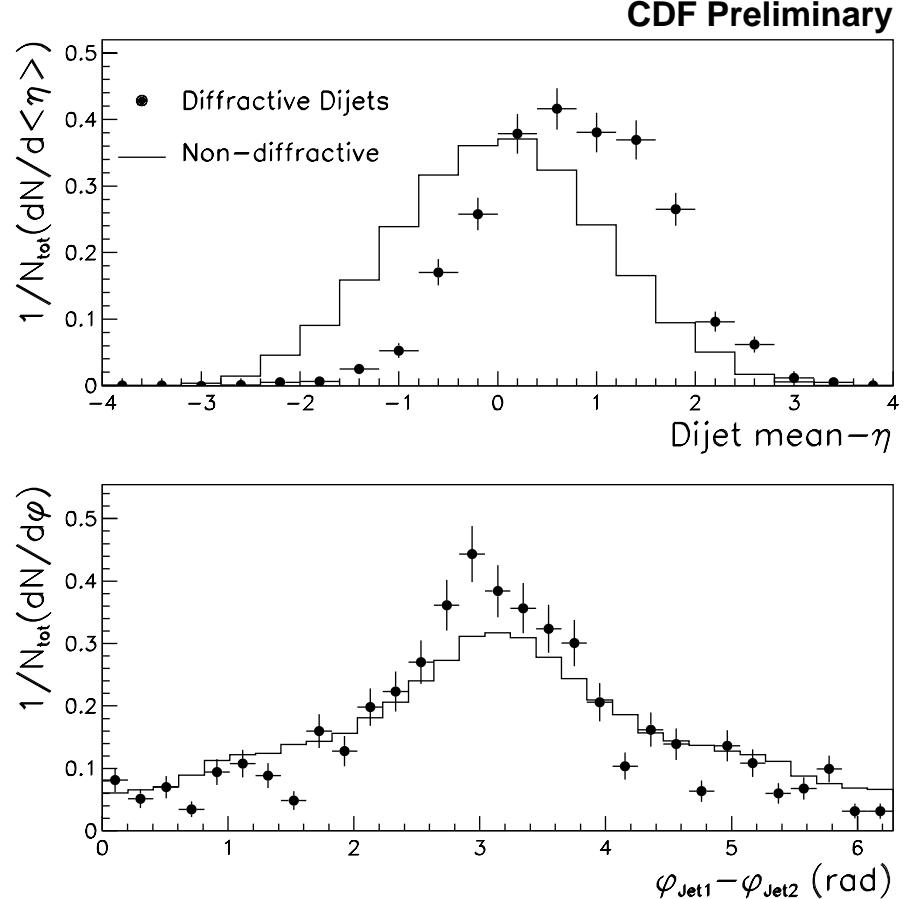
$0.04 \leq \xi \leq 0.10$

$|t| \leq 0.2\text{GeV}^2$

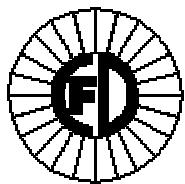
$E_T \geq 7\text{GeV}$

Absolute normalization

Stat errors only

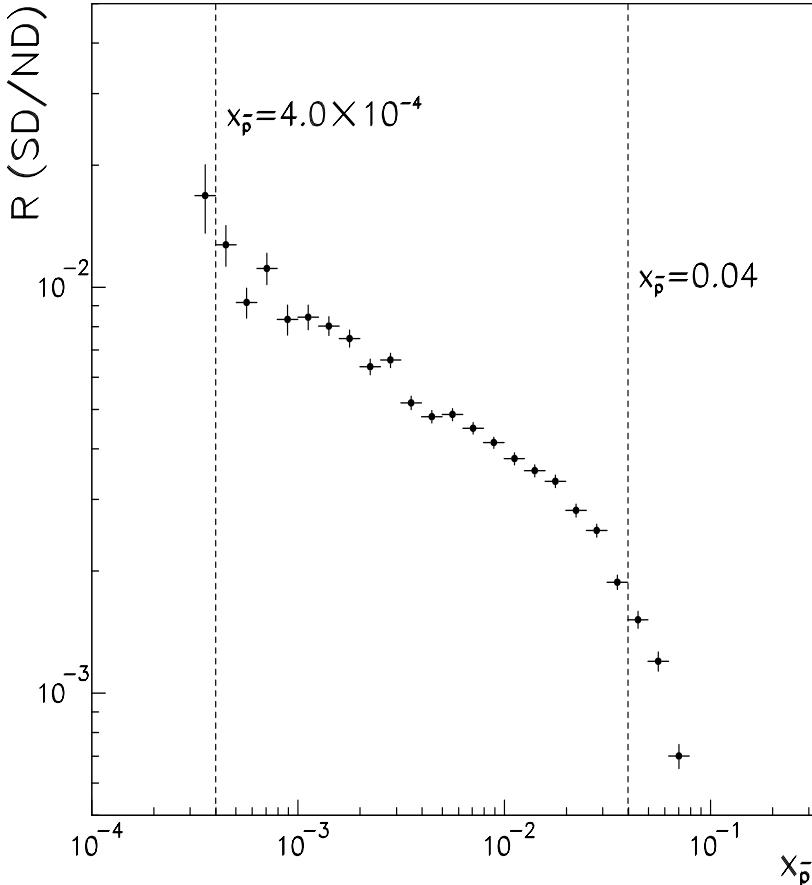


- Diffractive Dijet spectrum is steeper
- Diffractive Dijet system recoils against pot track
- Diffractive events are cleaner (fewer 3rd jets)

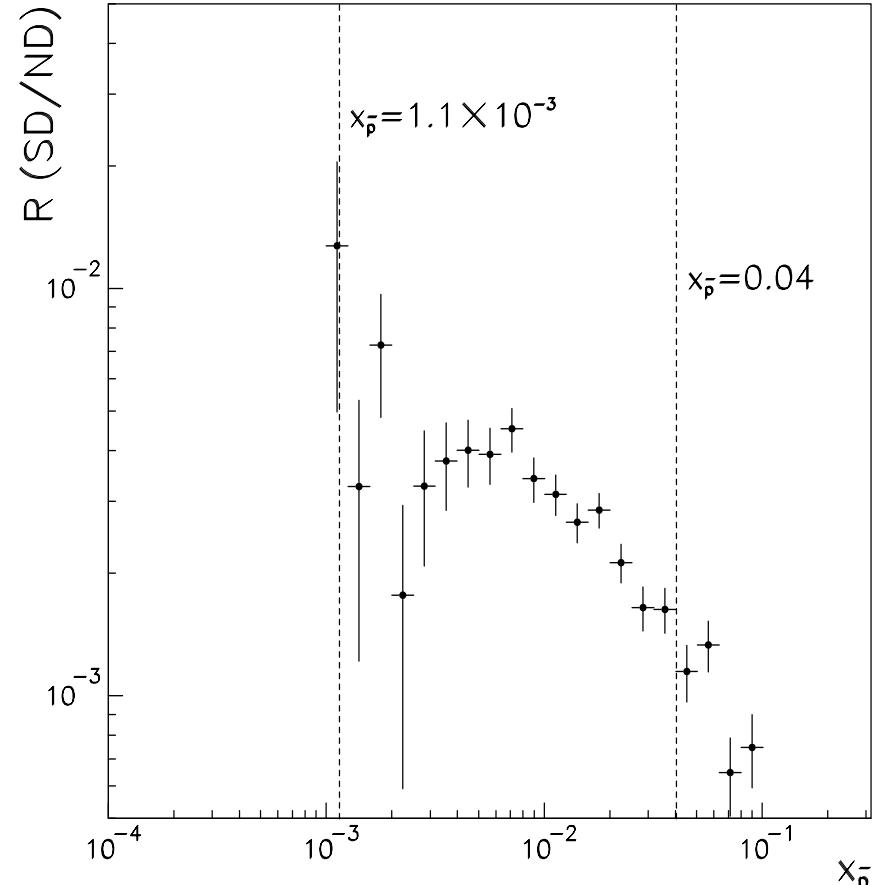


Diffractive to Non-Diffractive Ratio vs $x_{\bar{p}}$

$\sqrt{s} = 1.8 \text{TeV}$ CDF Preliminary



$\sqrt{s} = 630 \text{GeV}$ CDF Preliminary

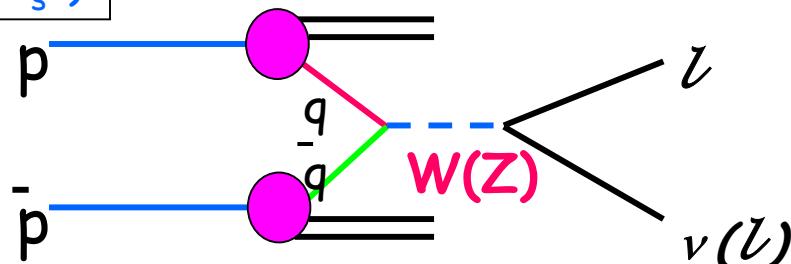


$$x_{\bar{p}} = \frac{E_T^{\text{Jet}_1} e^{-\eta_1} + E_T^{\text{Jet}_2} e^{-\eta_2}}{2 p_0^{\bar{p}}}$$

Rate of diffractive to non-diffractive events decreases with increasing $x_{\bar{p}}$

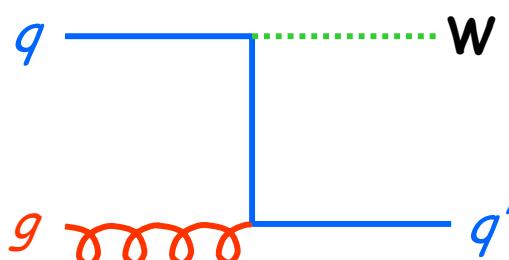
W&Z Production at the Tevatron

$O(\alpha_s^0)$



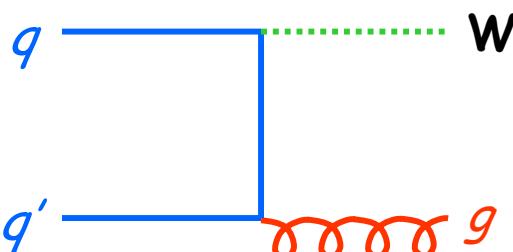
- Production dominated by $q\bar{q}$ annihilation ($\sim 60\%$ valence-sea, $\sim 20\%$ sea-sea)
- Due to very large $pp \rightarrow jj$ production, need to use leptonic decays ($BR \sim 11\% (W)$, $\sim 3\% (Z)$ per mode)

$O(\alpha_s)$



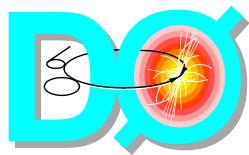
Modifications due to QCD corrections:

- Boson produced with transverse momentum ($\langle P_T \rangle \sim 10 \text{ GeV}$)
- Boson + jet events possible ($W + 1 \text{ jet} \sim 7\%$, $E_T^{\text{jet}} > 25 \text{ GeV}$)
- Inclusive cross sections larger (K factor $\sim 18\%$)
- Boson decay angular distribution modified

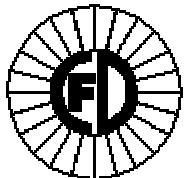


Benefits of studying QCD with W&Z Bosons:

- Distinctive event signatures
- Low backgrounds
- Large Q^2 ($Q^2 \sim \text{Mass}^2 \sim 6500 \text{ GeV}^2$)
- Well understood Electroweak Vertex



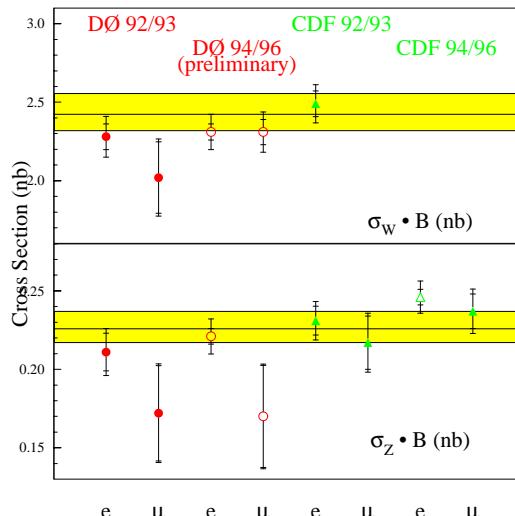
Inclusive W & Z Cross Sections



NEW

		$\sigma(W) \times BR(W \rightarrow l\nu) \text{ (nb)}$	$\sigma(Z) \times BR(Z \rightarrow ll) \text{ (nb)}$
DØ, e, 1b	Preliminary	$2.31 \pm 0.01 \pm 0.05 \pm 0.10$	$0.221 \pm 0.003 \pm 0.004 \pm 0.010$
DØ, e, 1a		$2.28 \pm 0.02 \pm 0.08 \pm 0.10$	$0.211 \pm 0.008 \pm 0.008 \pm 0.009$
DØ, μ , 1b	Preliminary	$2.31 \pm 0.08 \pm 0.10$	$0.170 \pm 0.023 \pm 0.023 \pm 0.007$
DØ, μ , 1a		$2.02 \pm 0.06 \pm 0.22 \pm 0.09$	$0.172 \pm 0.022 \pm 0.021 \pm 0.008$
CDF, e, 1b	Preliminary		$0.246 \pm 0.005 \pm 0.009$
CDF, e, 1a		$2.49 \pm 0.02 \pm 0.08 \pm 0.09$	$0.231 \pm 0.008 \pm 0.009$
CDF, μ , 1b	Updated		$0.237 \pm 0.011 \pm 0.009$
CDF, μ , 1a			$0.217 \pm 0.017 \pm 0.008$
CDF, μ , Run 1	Updated		0.233 ± 0.013

Updated



- Measurement errors:

- Stat \oplus Sys $\sim 2\%$

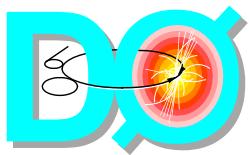
- Luminosity error $\sim 4\%$

- Theory error: $\sim 3\%$, NNLO, $O(\alpha_s^2)$

Dominated by PDF's at NLO... (need NNLO)

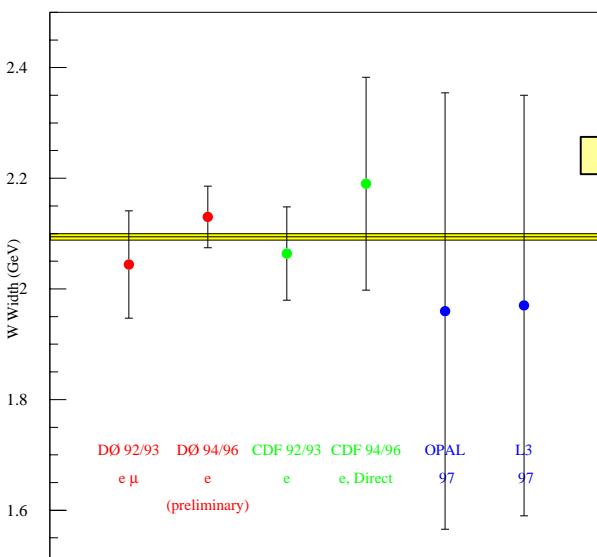
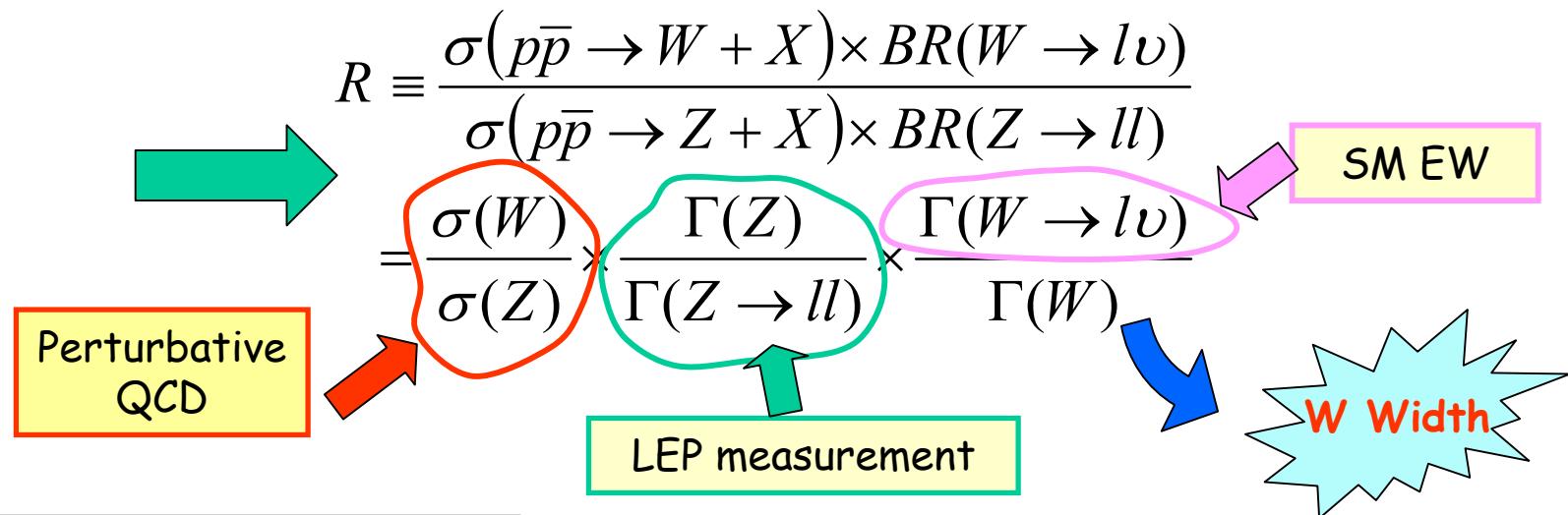
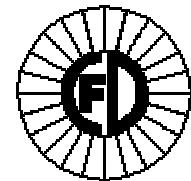
- NB: Luminosity determination: $L(DO) = 1.062 \times L(CDF)$

DO uses world avg. $\sigma(pp)_{inel}$, CDF uses own measurement



W Width

(Preliminary)



NEW

DØ (e + μ), 1b	$2.130 \pm 0.030 \pm 0.052$ GeV
DØ (e + μ), 1a	2.044 ± 0.097 GeV
CDF (e), 1a	$2.064 \pm 0.060 \pm 0.059$ GeV
CDF (e, direct), 1b	$2.19 \pm 0.17 \pm 0.09$ GeV
OPAL (1997)	$1.96 \pm 0.34 \pm 0.20$ GeV
L3 (1997)	1.97 ± 0.38 GeV

SM Prediction $\Gamma(W)=2.094 \pm 0.006$ GeV

Introduction to W , Z P_T Theory

$$\frac{d\sigma}{dp_T^2} \sim \frac{\alpha_s}{p_T^2} \ln\left(\frac{M_W^2}{p_T^2}\right) \left[v_1 + v_2 \alpha_s \ln^2\left(\frac{M_W^2}{p_T^2}\right) \right]$$

- **Large P_T region ($P_T \geq 30$ GeV):** Use pQCD, $O(\alpha_s^2)$ calculations exist

Ellis, Martinelli, Petronzio (83); Arnold & Reno (89);
Arnold, Ellis, Reno (89); Gonsalves, Pawlowski, Wai (89)

- **Small P_T region ($\Lambda_{QCD} < P_T < 10$ GeV):** Resum large logs

Altarelli, Ellis, Greco, Martinelli (84); Collins, Soper, Sterman (85)

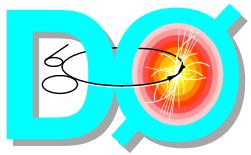
- **Very low P_T region ($P_T \sim \Lambda_{QCD}$):** Non-perturbative parameters extracted from data

b-space:

Parisi-Petronzio (79); Davies-Stirling (84); Collins-Soper-Sterman (85); Davies, Webber, Stirling (85); Arnold- Reno-Ellis (89); **AK**: Arnold-Kaufann (91); **LY**: Ladinsky-Yuan (94)

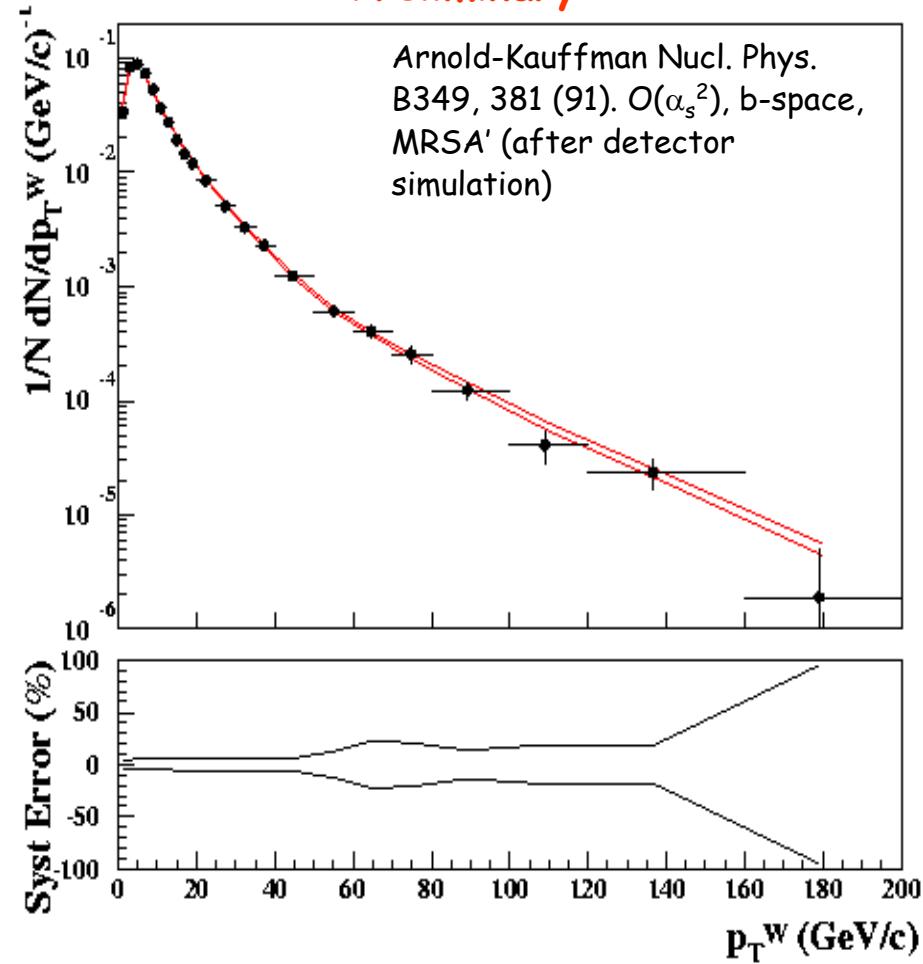
qt-space:

Dokshitser-Diaknov-Troian (80); Ellis-Stirling (81); Altarelli-Ellis-Greco-Martinelli (84); Gonsalves-Pawlowski-Wai (89); **ERV**: Ellis-Ross-Veseli (97); Ellis-Veseli (98)

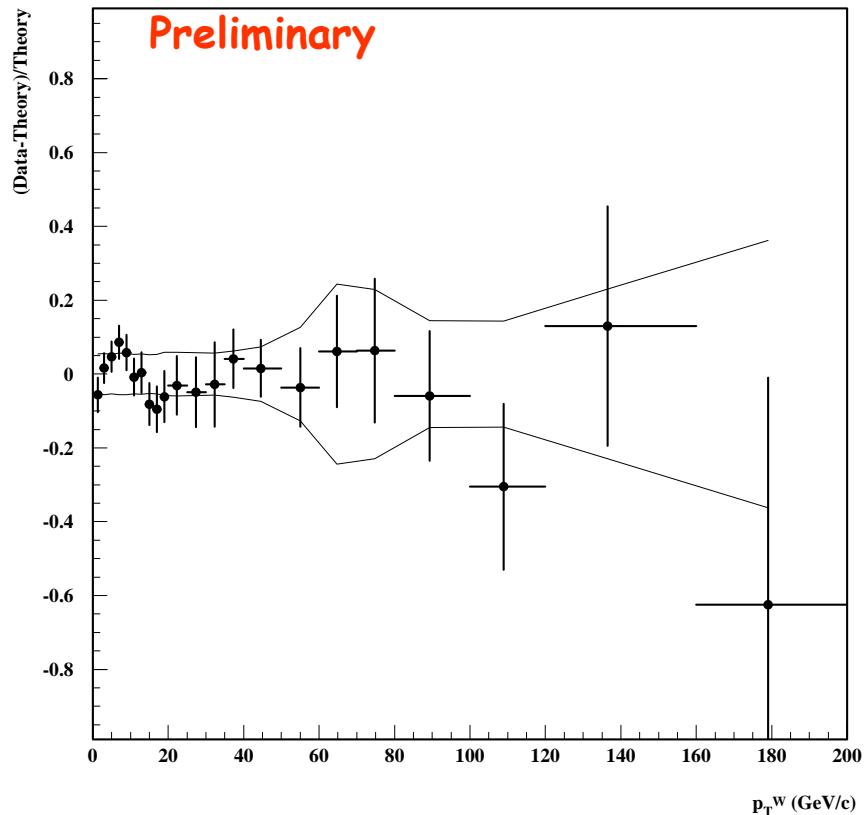


DO W P_T measurement

Preliminary



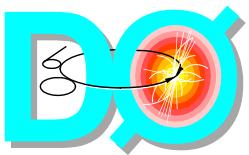
(Data-Theory)/Theory



$$\chi^2/\text{dof} = 7/19 \quad (p_T(W) < 120 \text{ GeV}/c)$$

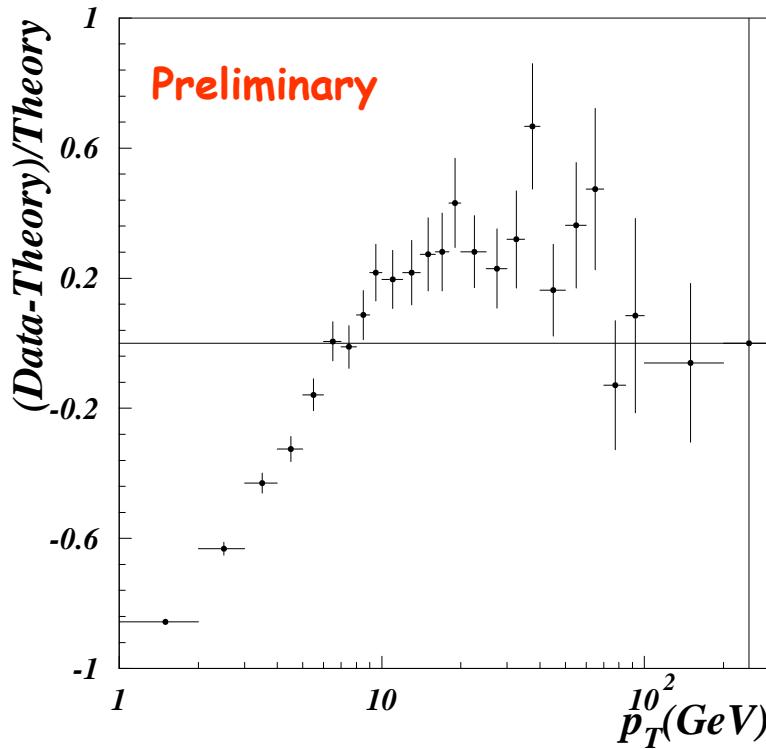
$$\chi^2/\text{dof} = 10/21 \quad (p_T(W) < 200 \text{ GeV}/c)$$

Resolution effects dominate at low P_T
High P_T dominated by statistics & backgrounds

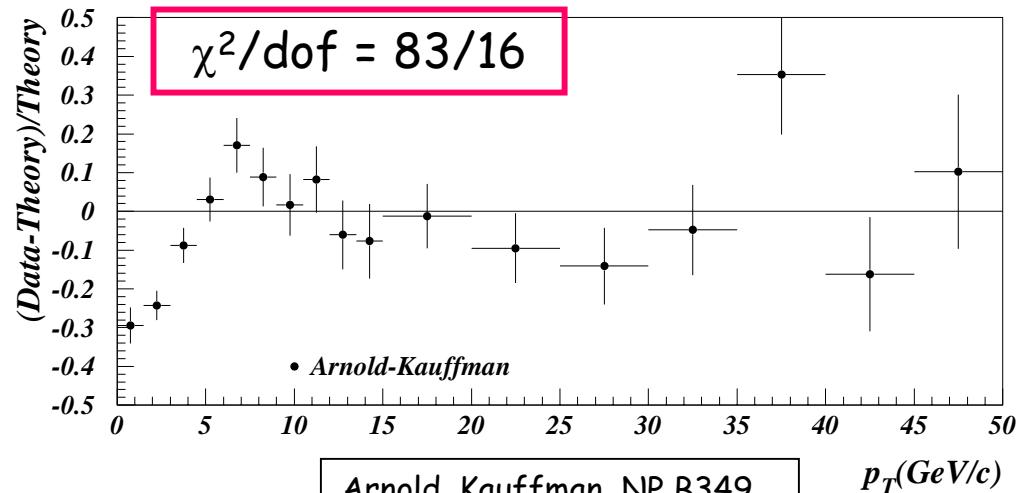
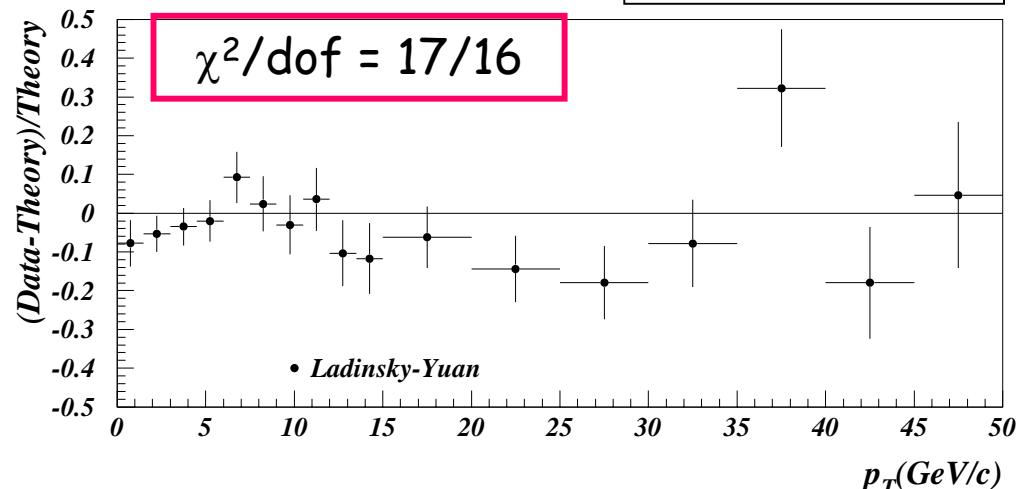


DO Z P_T measurement

Arnold, Reno, Nucl. Phys. B319, 37.
 $O(\alpha_s^2)$, MRSA', pQCD calculation



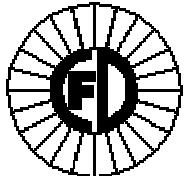
Ladinsky, Yuan, PRD 50, 4239 (94), $O(\alpha_s^2)$, b-space.



Arnold, Kauffman, NP B349,
381 (91), $O(\alpha_s^2)$, b-space.

Data resolution allows to discriminate
between different models for VB production.

CDF P_T measurements

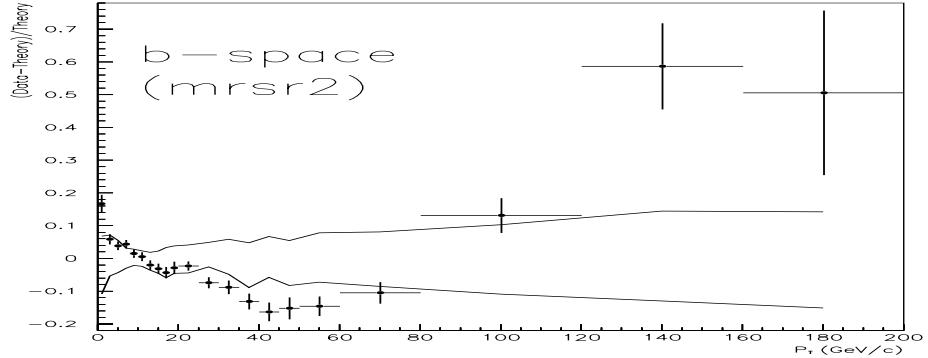


Ellis, Ross, Veseli, NP B503, 309
 (97). $O(\alpha_s)$, qT space, after
 detector simulation.

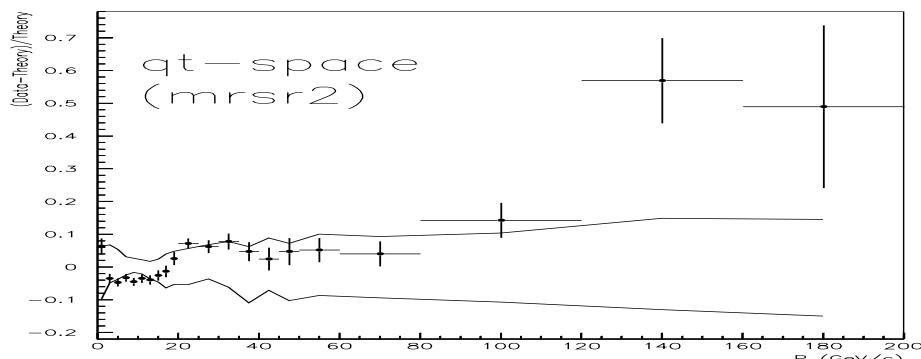
Preliminary

$$\frac{(D_a - T_{\text{QCD}})}{T_{\text{QCD}}}$$

CDF preliminary Run 1 Data

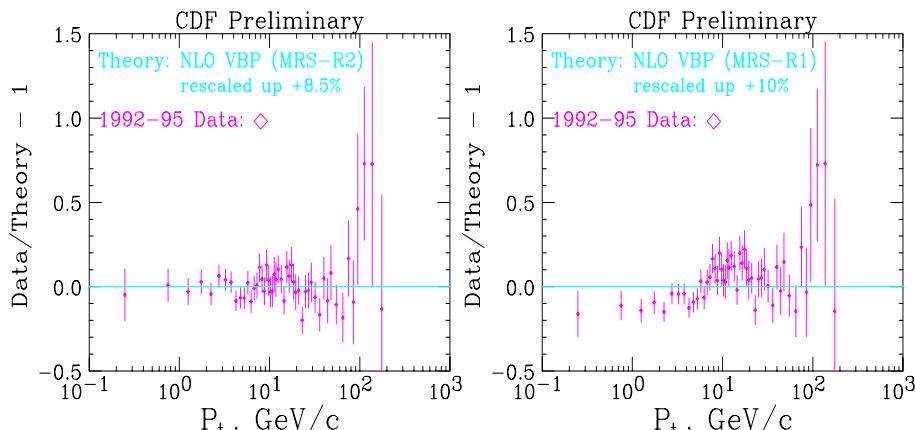
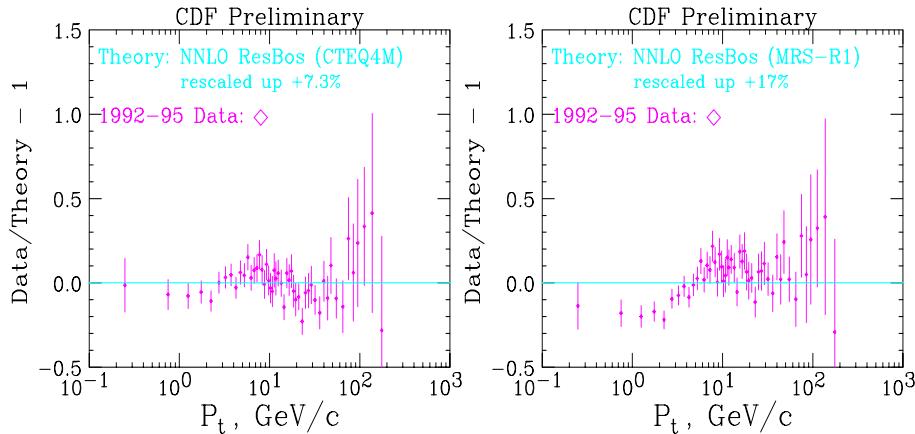


$\chi^2/d.o.f = 1.85$ ($P_T^W < 120$ GeV/c), 2.49 (< 200 GeV/c)

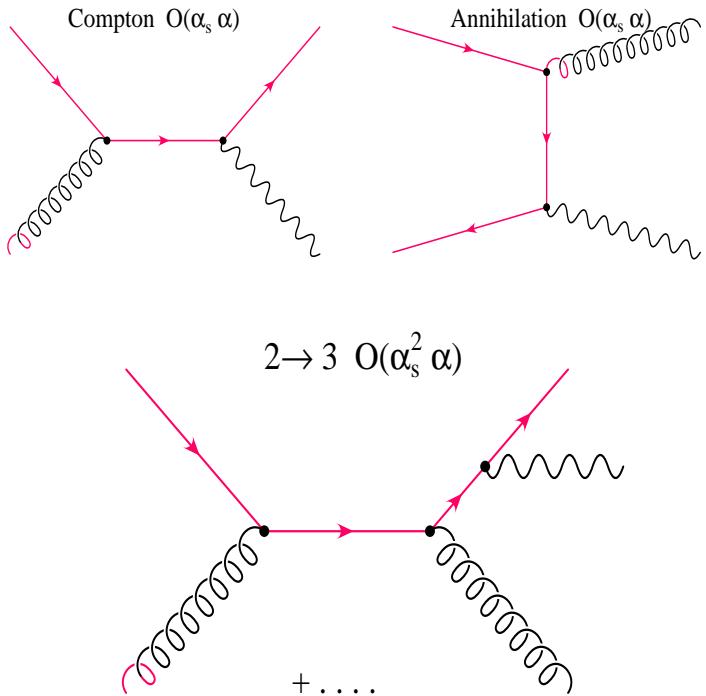


$\chi^2/d.o.f = 1.05$ ($P_T^W < 120$ GeV/c), 1.71 (< 200 GeV/c)

ResBos: Balas, Yuan, PRD 56, 5558 (1997), $O(\alpha_s^2)$, b-space
 VBP: Ellis, Veseli, NP B511, 649 (1998), $O(\alpha_s)$, qt-space

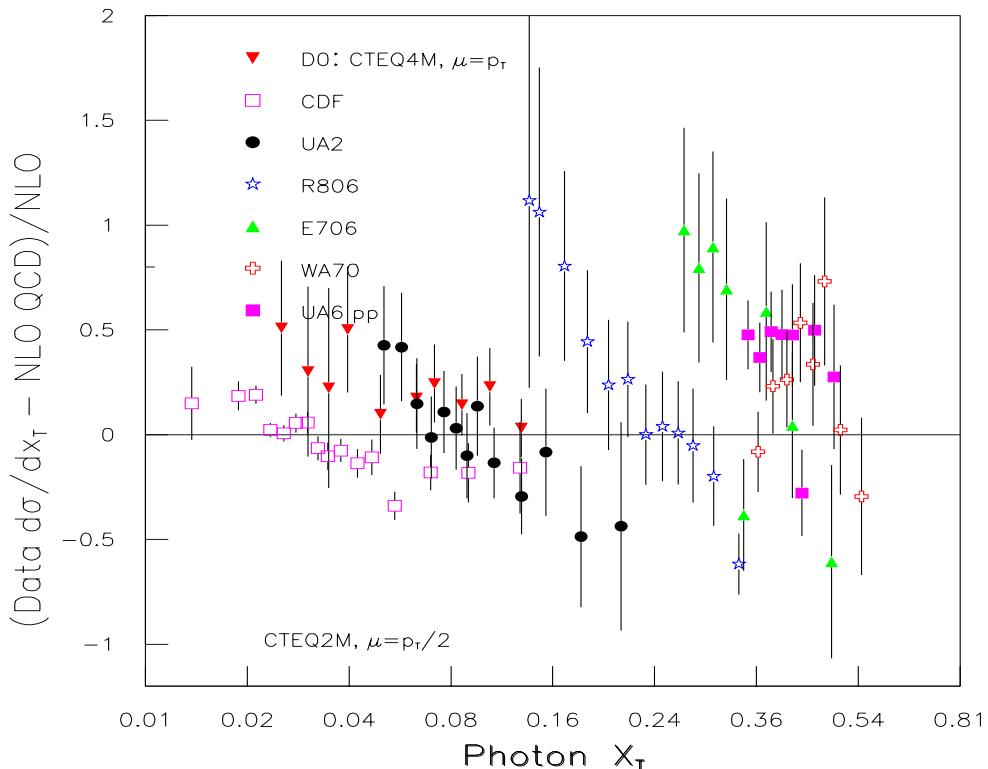


Photon production at the Tevatron



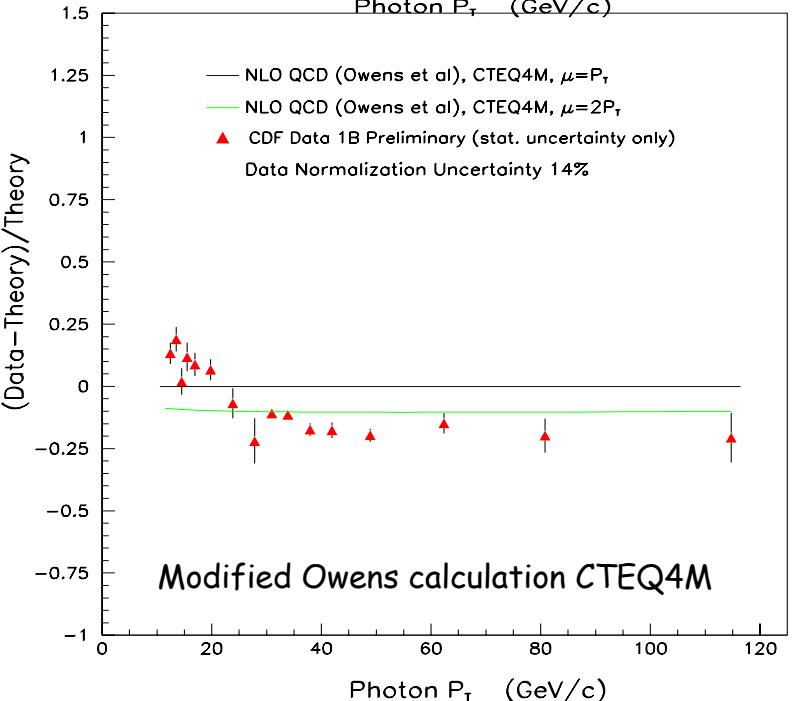
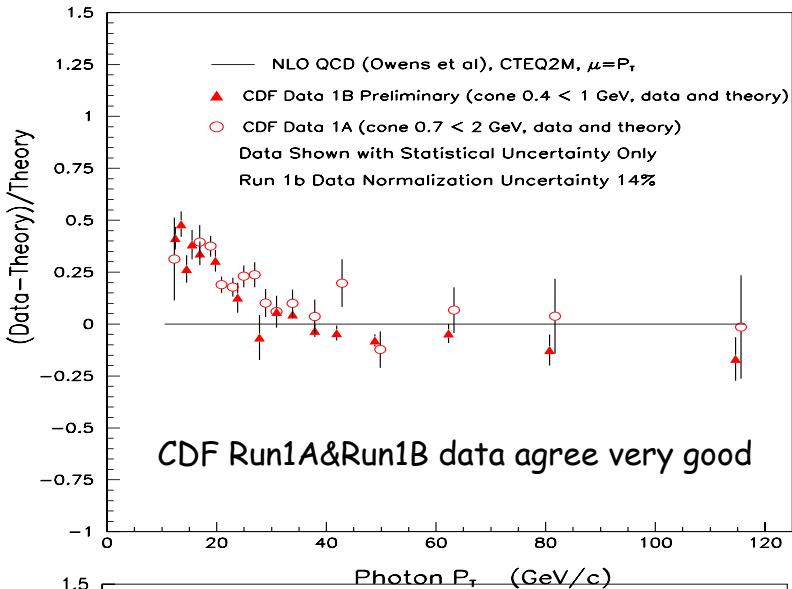
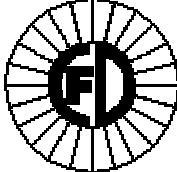
Recent Direct Photon Experiments

exp	cme	beam	target	Pt	x
CDF	1800	pbar	p	10-130	.01-.14
D0	1800	pbar	p	20-130	.02-.14
E706	~30	p	p,Be, ~40 pions	3-12	.2-.7
UA6	24.3	pbar	p	4-7	.3-.6
WA70	23.0	p pi	p	4-6.5	.35-.55



All the measurements show discrepancies between data and NLO QCD theory.

CDF Inclusive Photon Cross Section



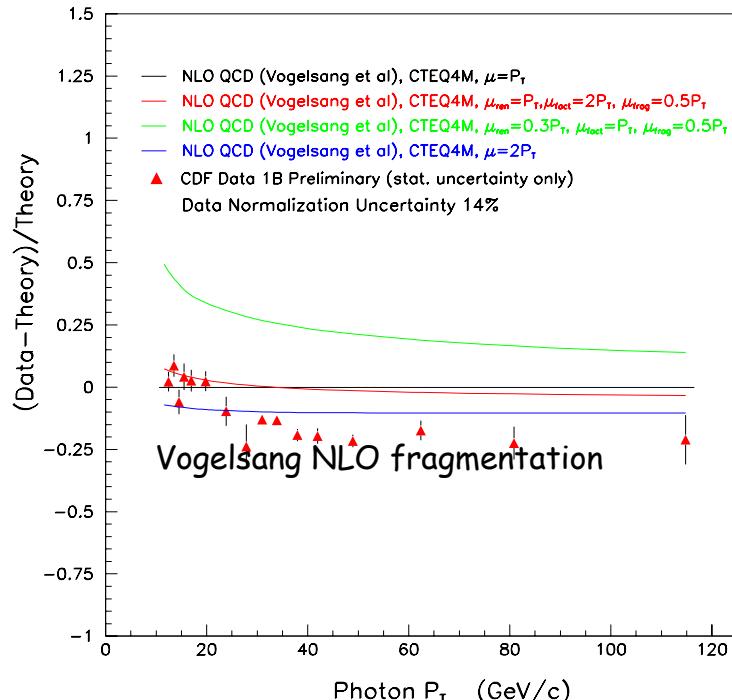
Evolution of Theoretical Calculations

Owens et al.

- Change in isolation cut normalization up by 10%
- Lower cutoff of 2 to 3 body interaction up by 5%
- CTEQ4M replaced CTEQ2M slope increase by 15%

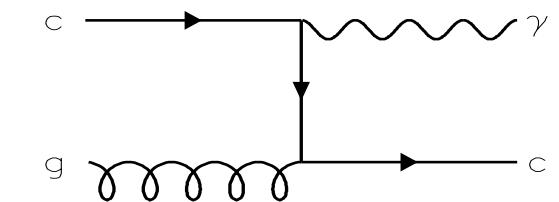
Vogelsang et al.

- NLO fragmentation, 3 theory scales to change

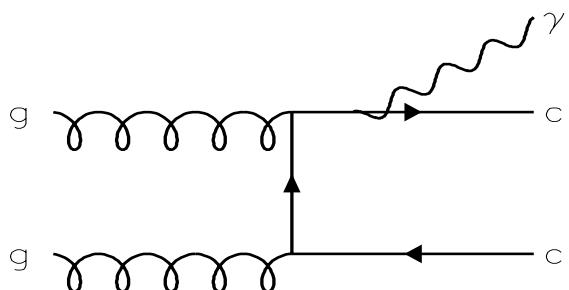


Agreement between data and theory is better above 35 GeV. Still bad at low γP_T

Photon + Muon Production



$$cg \rightarrow \gamma c \rightarrow \gamma X$$

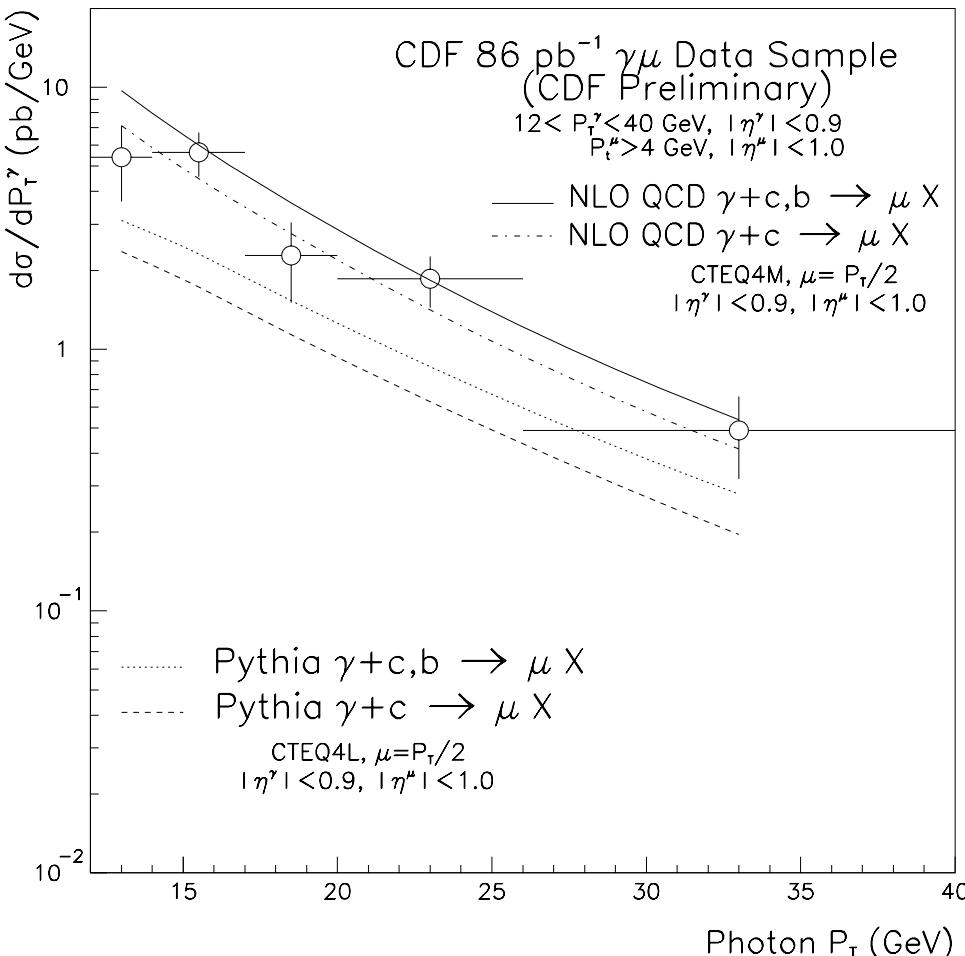
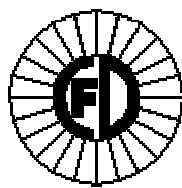


$$gg \rightarrow \gamma c\bar{c} \rightarrow \gamma X$$

- NLO corrections are large due to $gg \rightarrow cc \rightarrow cc\gamma$ where c-quark radiates
- Muon backgrounds from K/π decay and hadron puchthrough

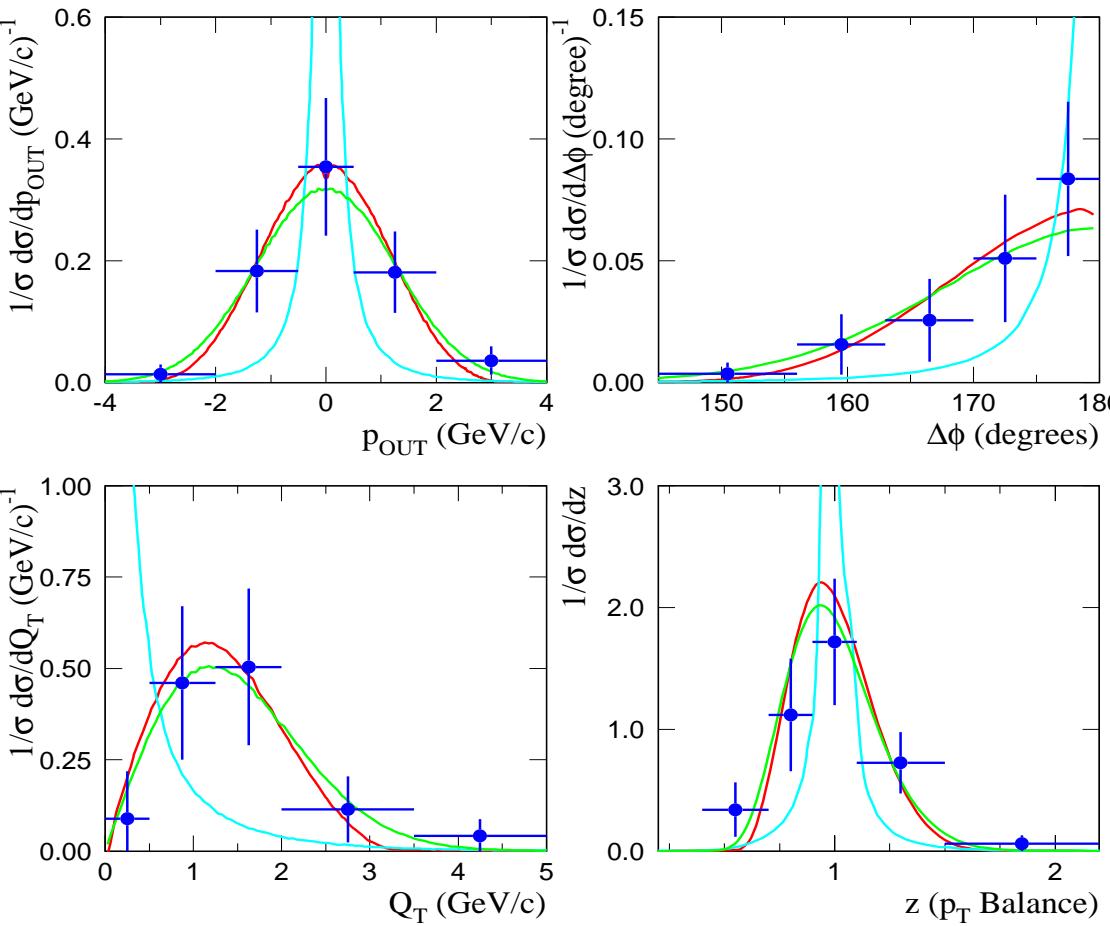
Photon + Muon Cross Section

Measure the charm content of proton



Charm content of proton agrees with NLO QCD with current statistics

E706 Direct Photon and π^0 Production



$\pi^- \text{Be} \rightarrow \gamma \text{X}$ at 515 GeV/c

$p_T^\gamma > 4.0 \text{ GeV}/c$

$-0.80 < y^\gamma < 0.80$

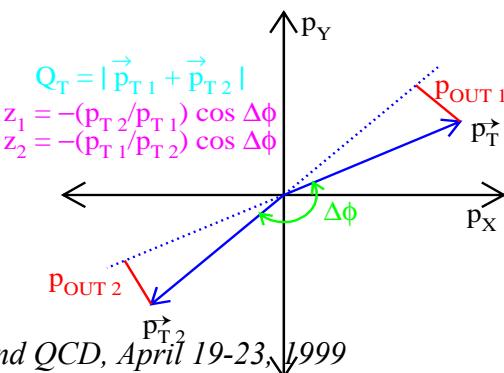
$\Delta\phi > 105^\circ$

$M > 10 \text{ GeV}/c^2$

— Resummed (RESBOS)

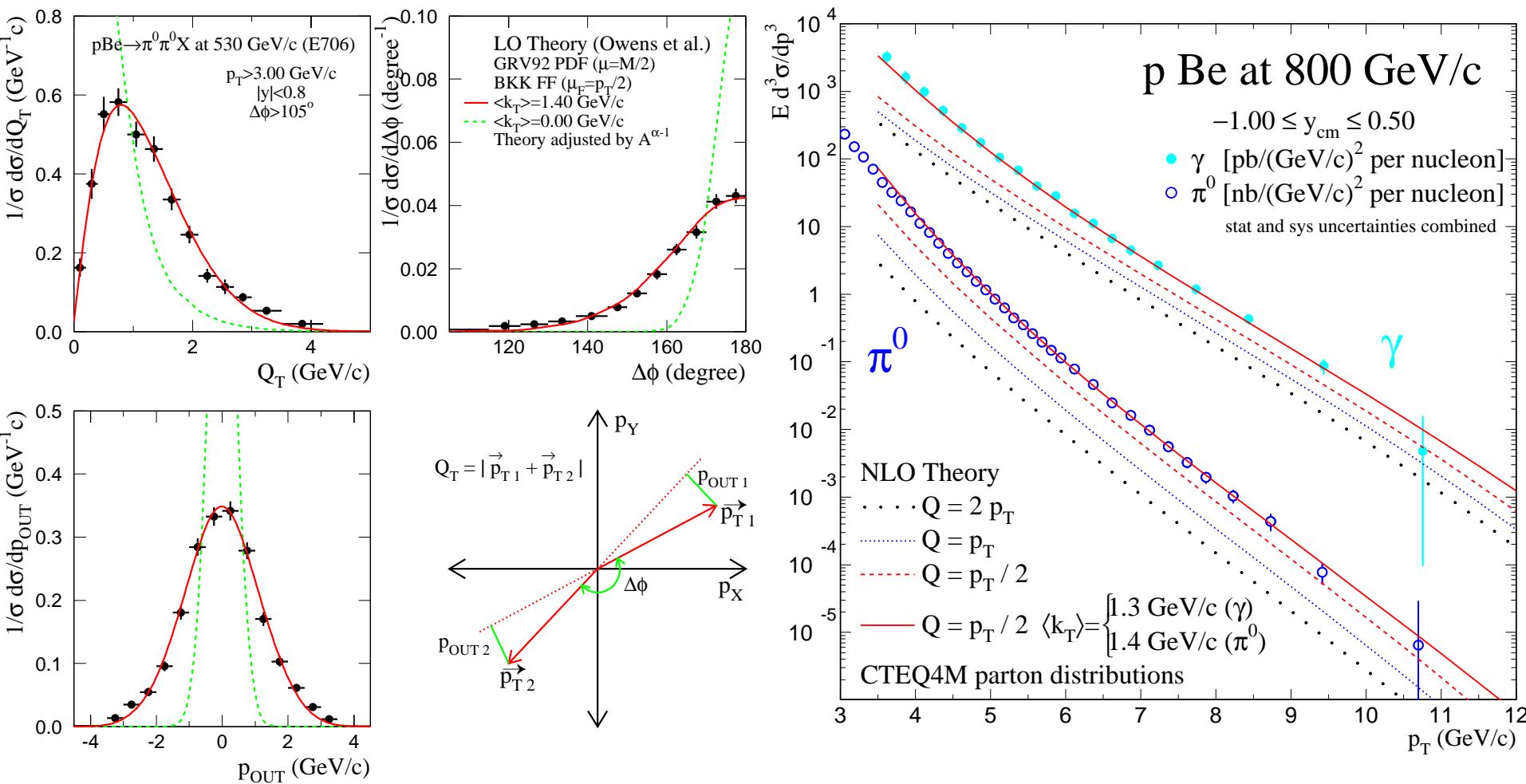
— NLO (Bailey et al.)

— PYTHIA ($\langle k_T \rangle = 1.1 \text{ GeV}/c$)



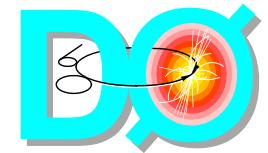
- Initial state soft gluon radiation (k_T) effects visible in direct-photon pair production
- NLO resummed calculations do not exist for π^0 Production
- Develop phenomenological model to incorporate k_T effects to NLO pQCD calculations

E706 Direct Photon and π^0 Production

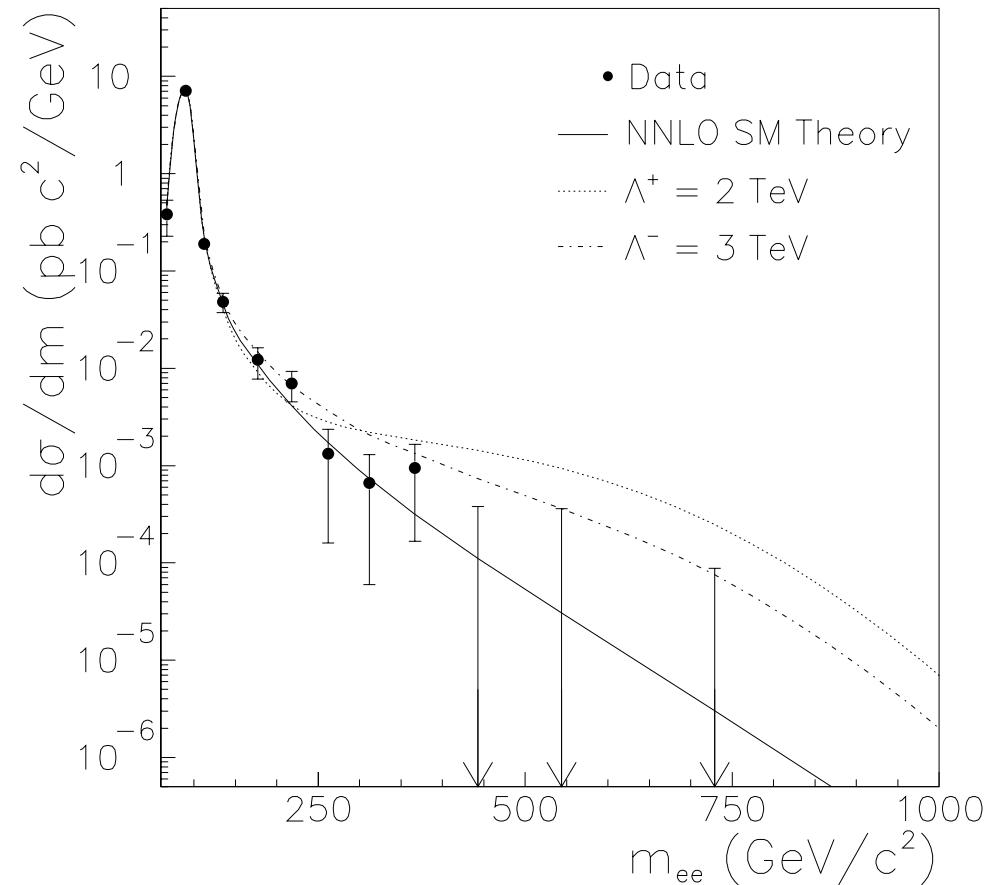


k_T enhanced NLO pQCD model reproduces kinematic distributions and invariant cross sections

DO High Mass Drell-Yan Cross Section



- Measure $d\sigma/dm$ for $p\bar{p} \rightarrow e^+e^- + X$



- Compare to SM Drell-Yan prediction and search for evidence of compositeness

• Compositeness Models

- Quarks and Fermions have common substructure
- Interaction manifested through four-fermion contact term
- Consider different chiral models categorized by signed interaction strengths

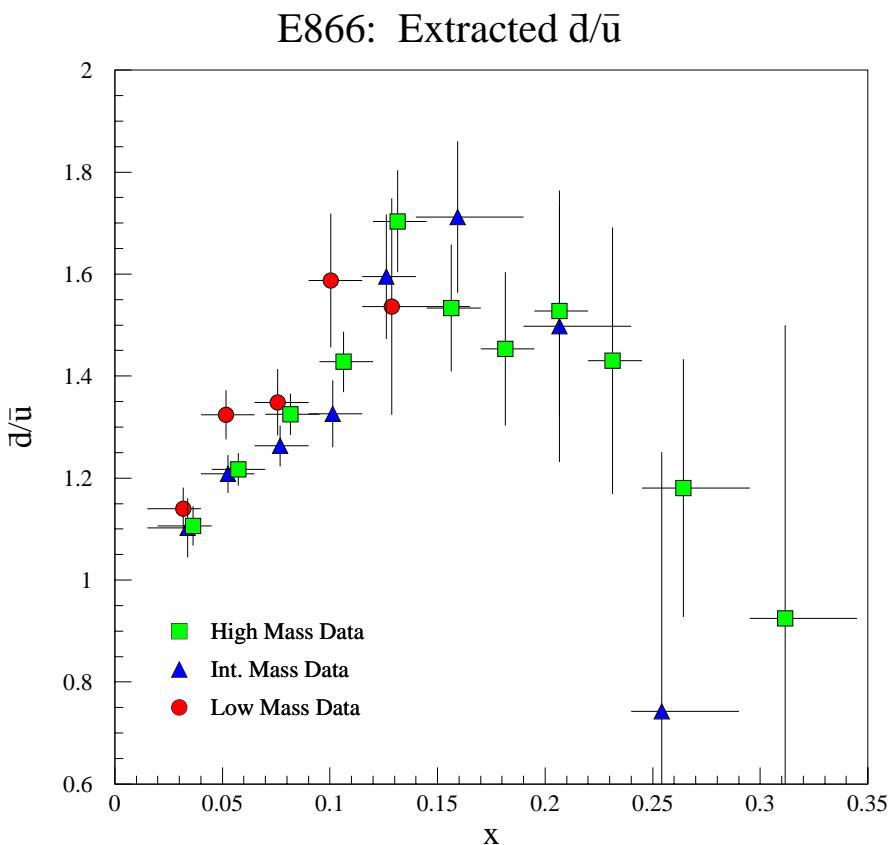
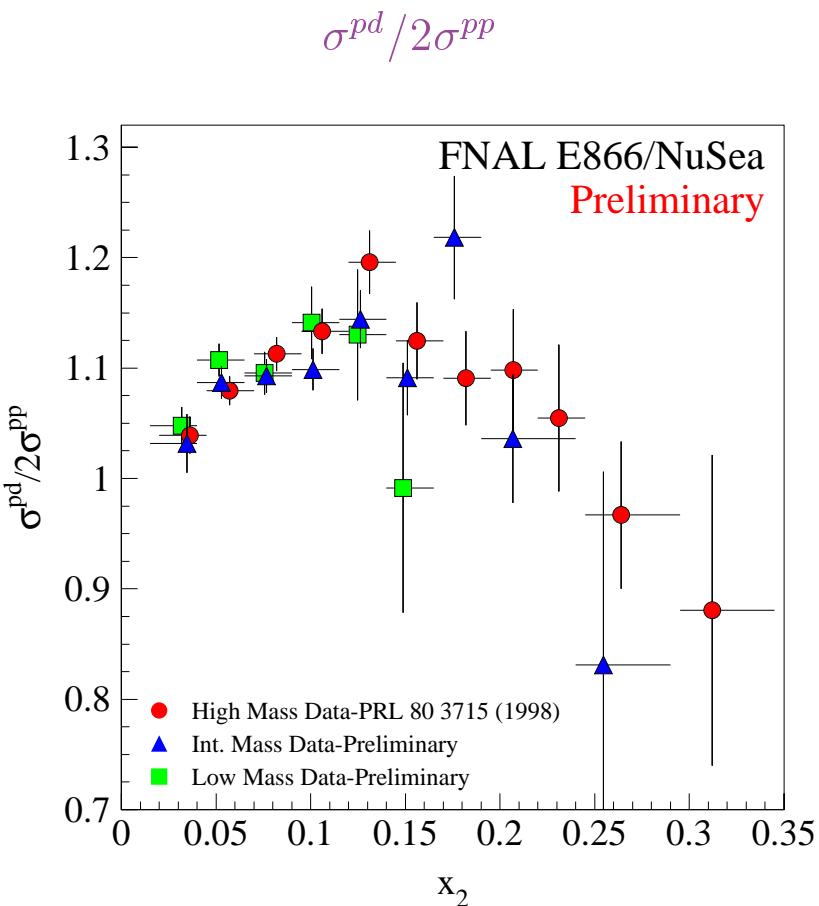
Mfd	Λ^+ (TeV)	Λ^- (TeV)
LL	3.3	4.2
LR	3.4	3.6
RL	3.3	3.7
LL+RR	4.2	5.1
LR+RL	3.9	4.4
LL-LR	3.9	4.5
RL-RR	4.0	4.3
VV	4.9	6.1
AA	4.7	5.5

Best limits to date on quark-electron compositeness

E866/NuSea Antiquark asymmetry in the Nucleon Sea

800GeV p+p & p+d $\rightarrow \mu^+ \mu^- X$

Consider three mass ranges

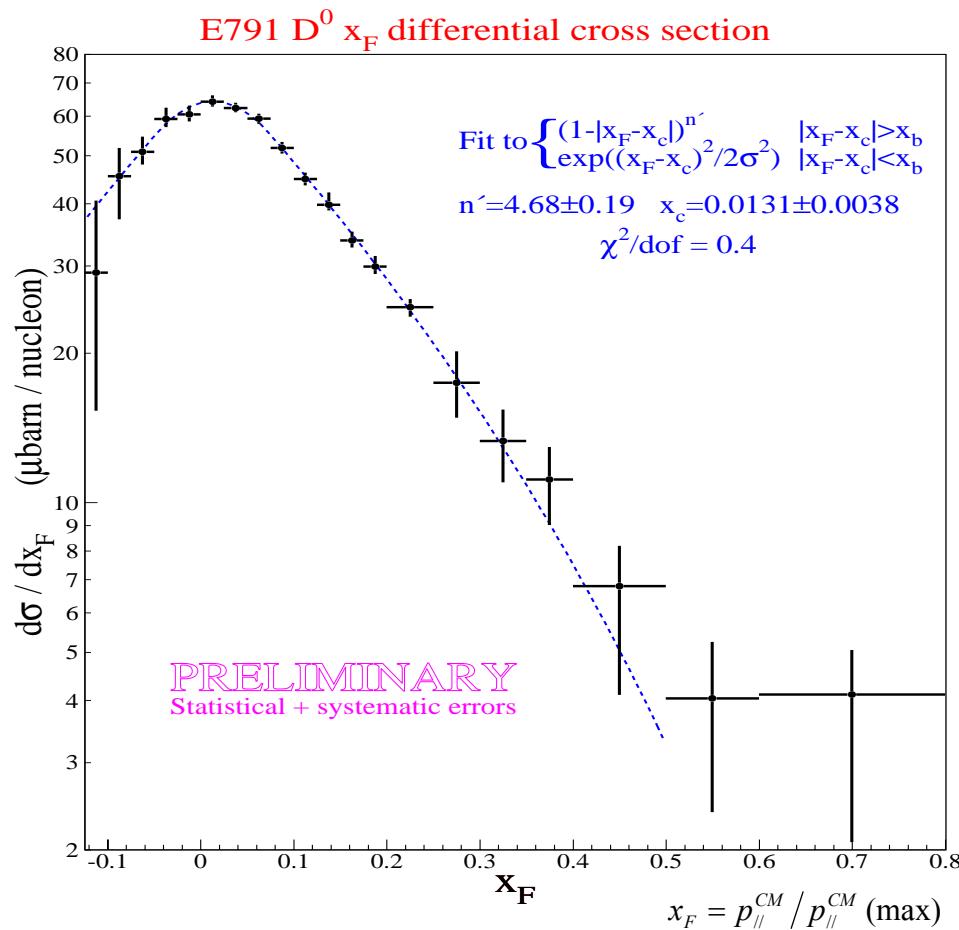
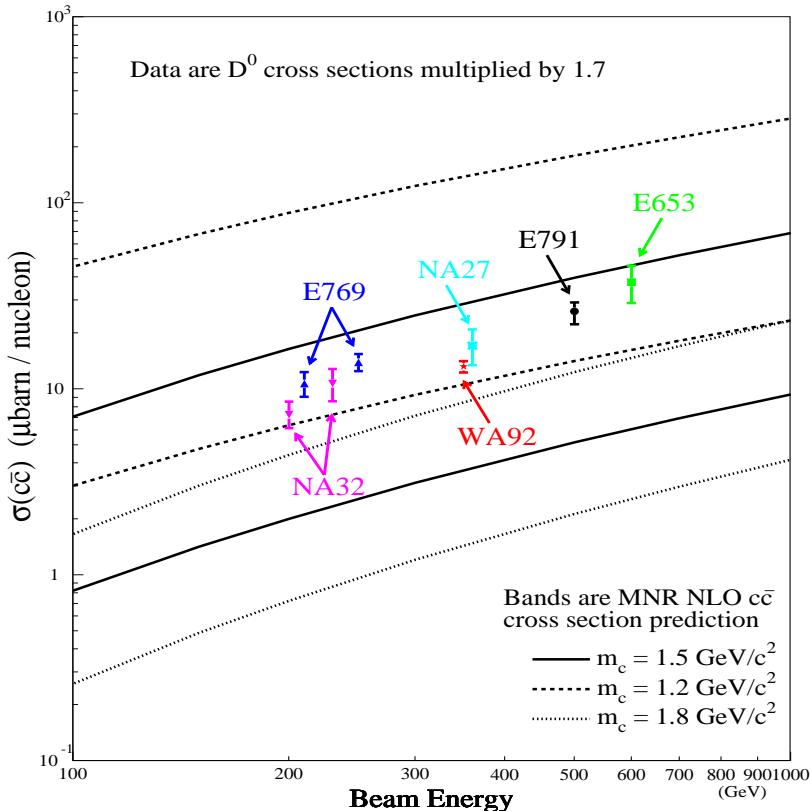


\bar{d}/\bar{u} Decreases for $x > 0.2$

E791 Hadroproduction of Charm

500GeV π^- beam on nuclear target \Rightarrow 89,000 D^0 events

$$\sigma(D^0 + \bar{D}^0; x_F > 0) = 15.4 \pm \frac{1.8}{2.3} \mu\text{b} / \text{nucleon}$$



Good agreement with previous D^0 results & theory

First measurement of differential x-sec versus x_F .

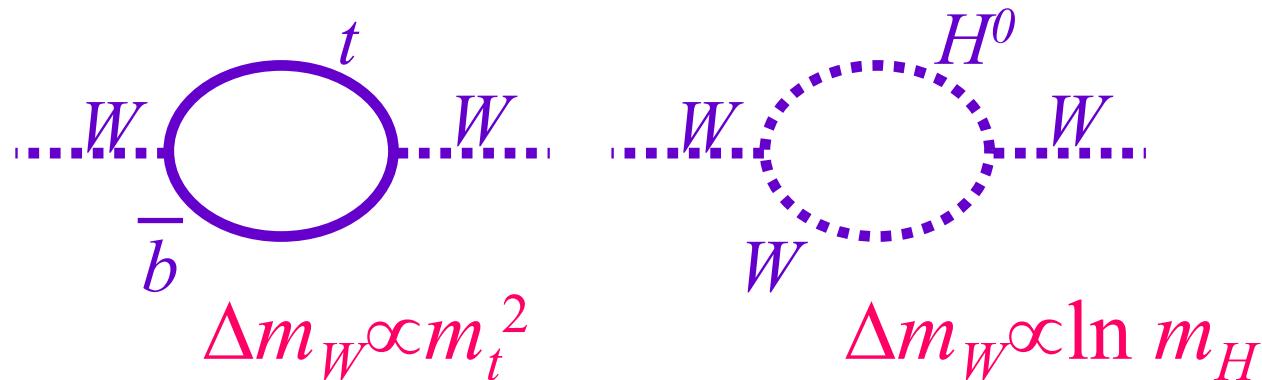
• x_F distribution peaks forward of $x_F=0$

Production dominated by gg fusion $\Rightarrow g$ in incident π are harder than those in the nucleon target.

Working on comparison with theoretical models

Measurement of the W Boson Mass

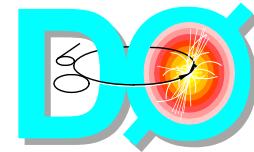
- EW symmetry breaking gives mass to the W boson
- determined at tree level by m_Z or $\sin^2\theta_W$, G_F , α
- dominant radiative corrections



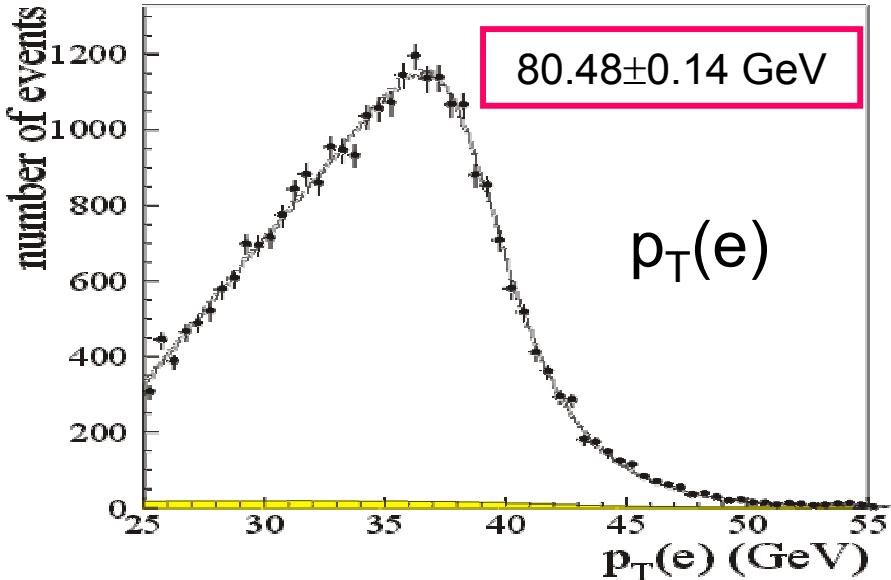
- important test of the Standard Model
- constrain Higgs boson mass

- W mass determined by likelihood fit to Monte Carlo distributions including backgrounds, efficiencies and detector resolutions

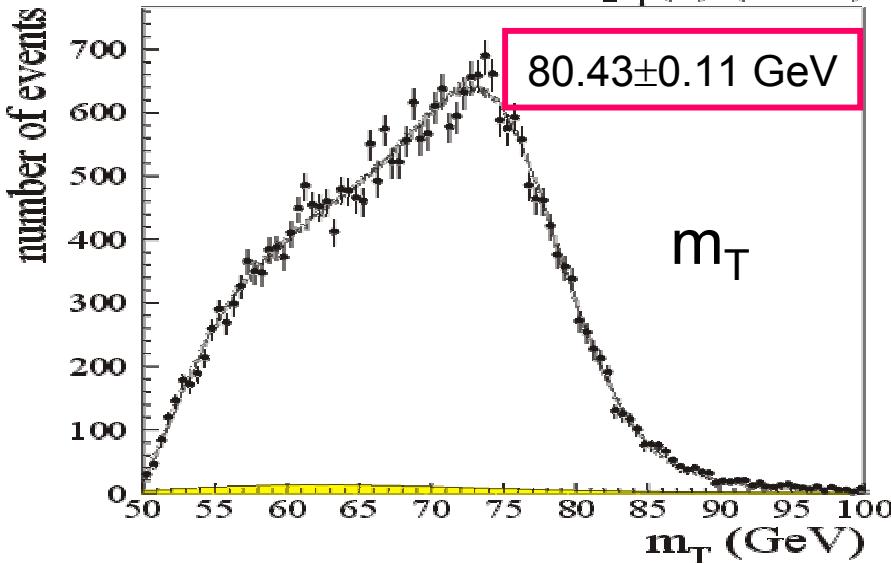
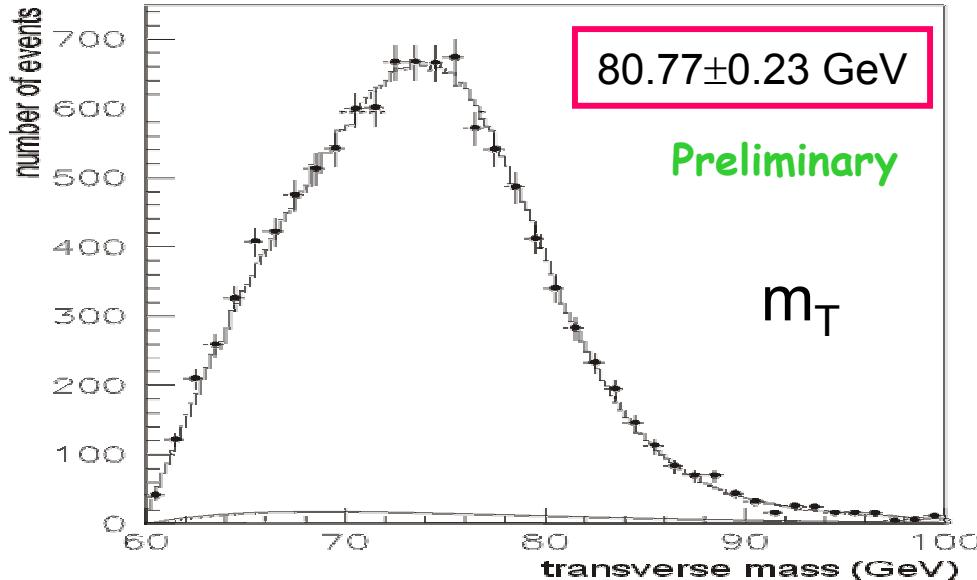
W Boson Mass from D0



Central Electrons



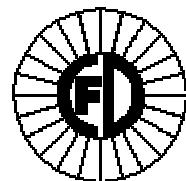
Forward Electrons



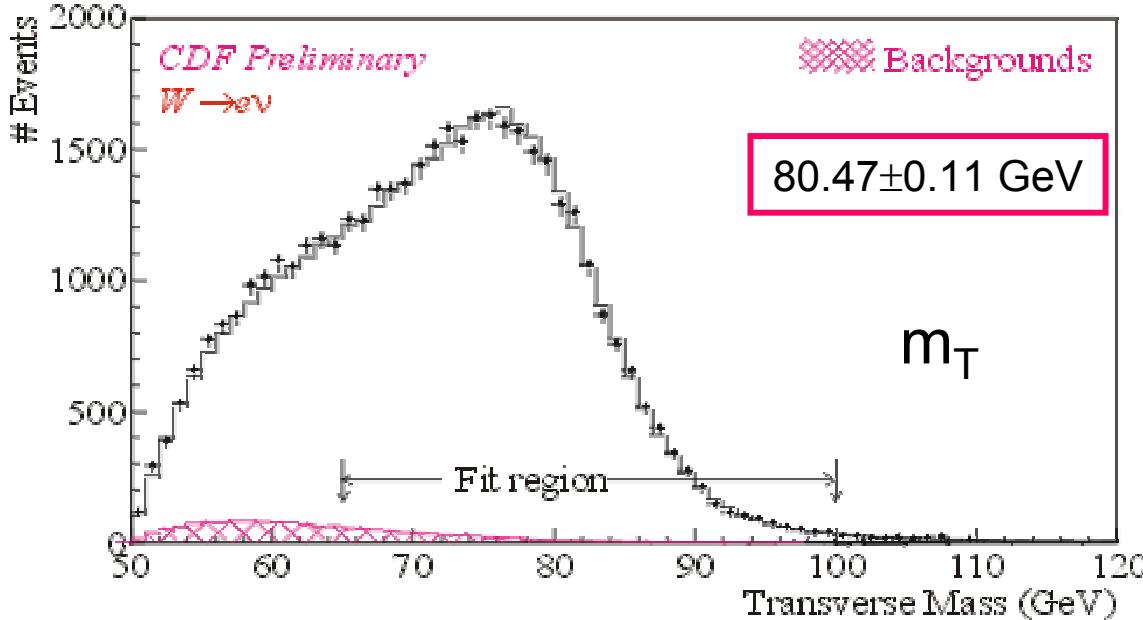
uncertainties	central	forward
statistical	70 MeV	105 MeV
scale	65 MeV	180 MeV
exp syst	60 MeV	105 MeV
theory	30 MeV	40 MeV

Preliminary

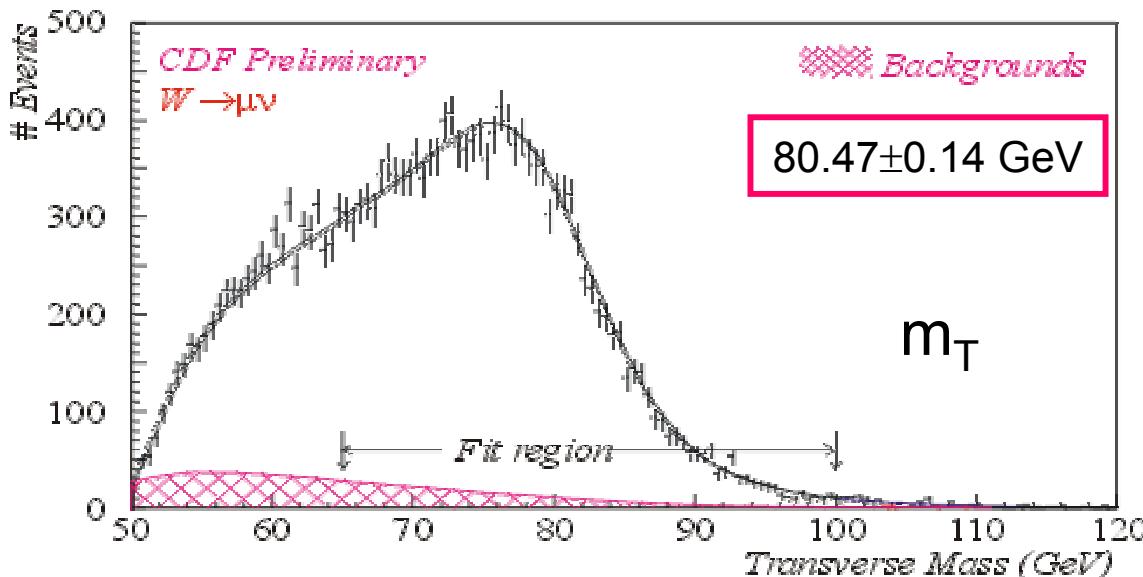
$80.47 \pm 0.09 \text{ GeV}$



W Boson Mass from CDF



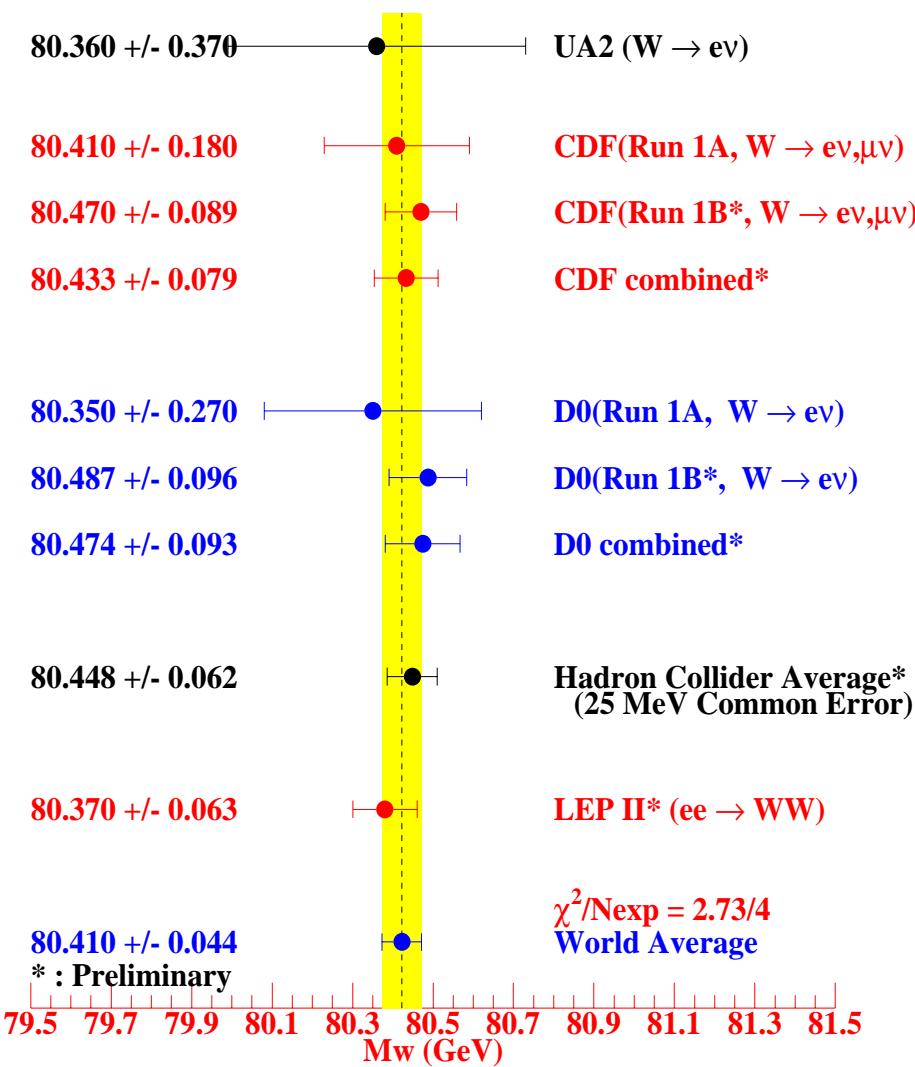
uncertainties	ev	$\mu\nu$
statistical	65 MeV	100 MeV
scale	75 MeV	85 MeV
exp syst	45 MeV	55 MeV
theory	25 MeV	18 MeV



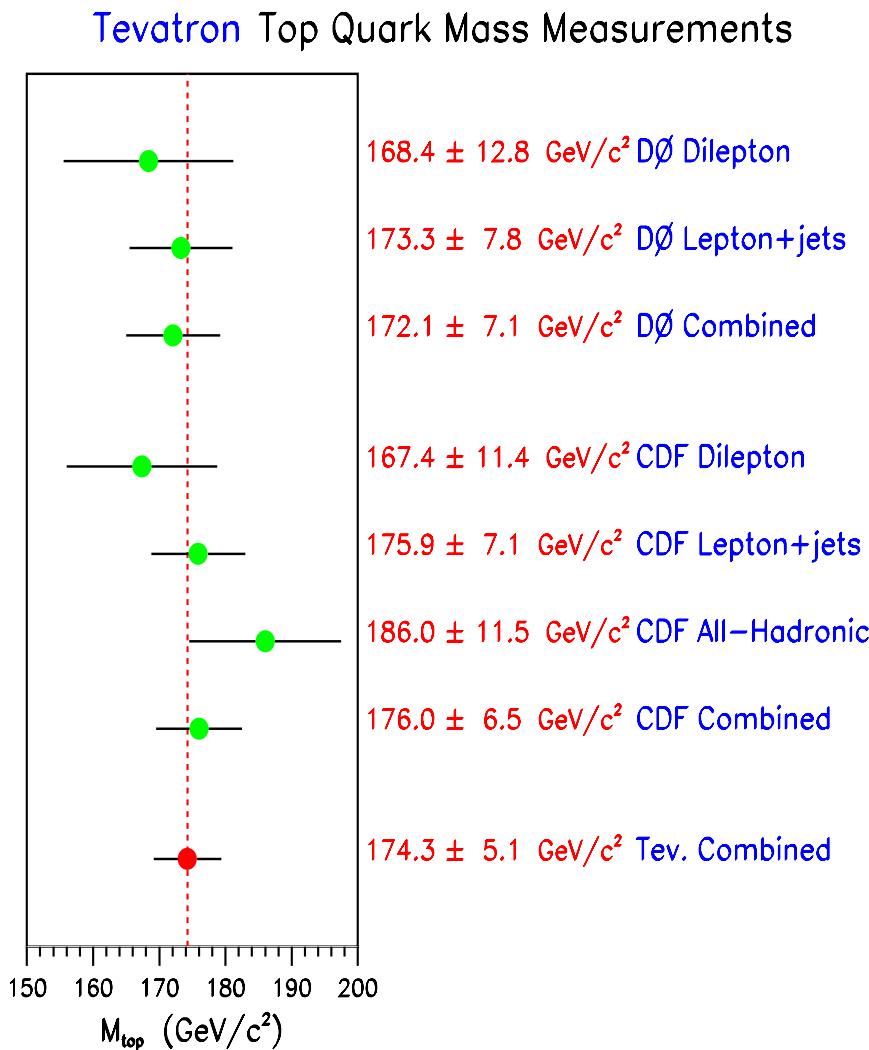
Preliminary

$80.43 \pm 0.08 \text{ GeV}$

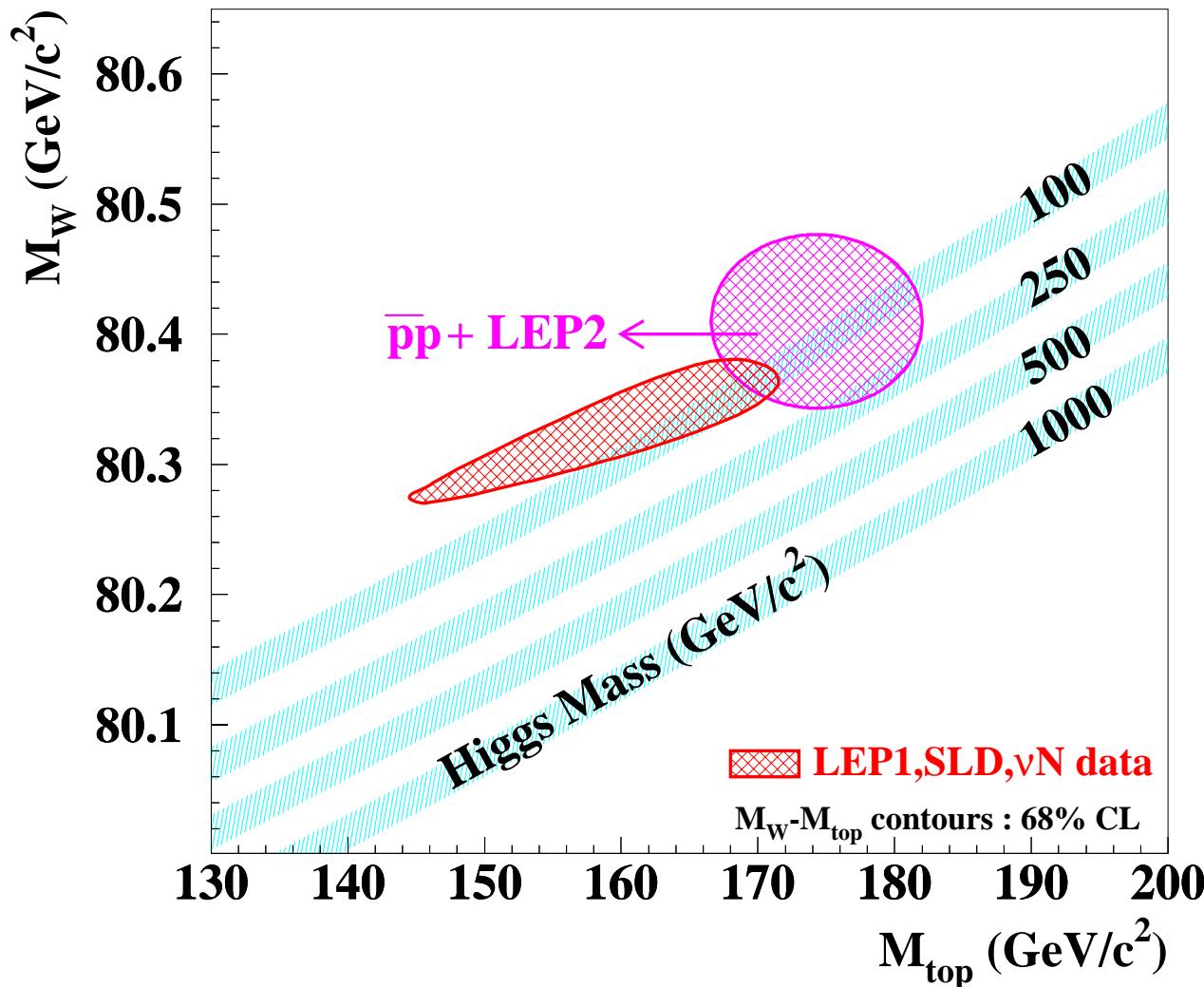
W Mass measurements



Top Mass measurements



Higgs Mass constraint



SM predictions for m_H by Degrassi et al. PL B418, 209 (1998) & PL B394, 188 (1997)

Measurement of ε'/ε by KTeV

CP Violation

- **Indirect** (asymmetric $K^0\bar{K}^0$ oscillations)

$$K_L \sim K_{\text{odd}} + \varepsilon K_{\text{even}}$$
$$K_S \sim K_{\text{even}} + \varepsilon K_{\text{odd}} \quad (\varepsilon \sim 0.2\%)$$

- **Direct** (CP violation in decay amplitude)

$K_{\text{odd}} \rightarrow \pi\pi$ parametrized by ε'

- Direct contribution is different for

$\square \pi^+\pi^-$ vs $\pi^0\pi^0$. Measure ε'/ε from

$$1 + 6R_e(\varepsilon'/\varepsilon) \approx \frac{\Gamma(K_L \rightarrow \pi^+\pi^-)/\Gamma(K_S \rightarrow \pi^+\pi^-)}{\Gamma(K_L \rightarrow \pi^0\pi^0)/\Gamma(K_S \rightarrow \pi^0\pi^0)}$$

Theoretical Predictions for $\text{Re}(\varepsilon'/\varepsilon)$

Superweak Model: predicts zero

Standard Model: $(0-20)\times 10^{-4}$

depending on inputs and method

Past Measurements

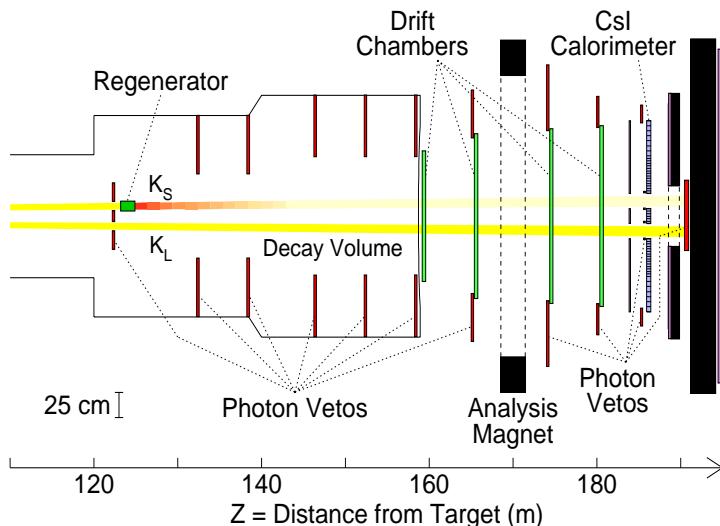
$(23 \pm 6.5) \times 10^{-4}$ CERN NA31 (1993)

$(7.4 \pm 5.9) \times 10^{-4}$ FNAL E731 (1993)

evidence for direct CP violation

Measurement of ε'/ε by KTeV

Collect K_L and K_S Decays Simultaneously

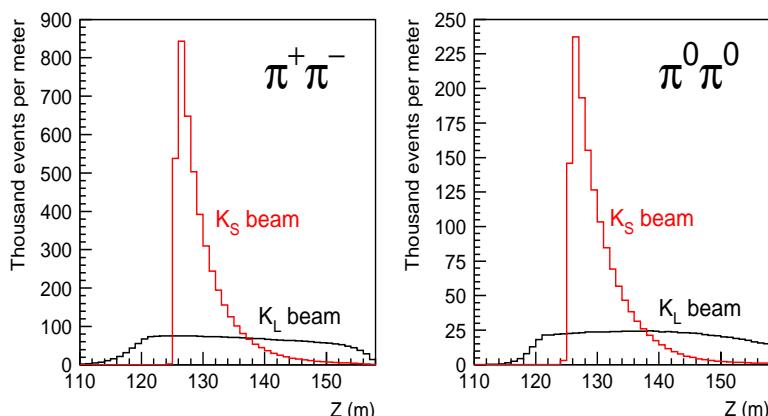


- 800GeV proton beam produces two K^0_L parallel beams
- Regenerator in one of the beams converts K^0_L to K^0_S
- Kaon decays are collected concurrently with KTeV detector

Samples based on ~23% of data
collected during 1996-1997

Samples	Background	Net Yield
$K_S \rightarrow \pi^+\pi^-$	0.09%	4,515,928
$K_S \rightarrow \pi^0\pi^0$	1.23%	1,422,923
$K_L \rightarrow \pi^+\pi^-$	0.08%	2,607,274
$K_L \rightarrow \pi^0\pi^0$	0.74%	862,254

Vertex Z Distributions



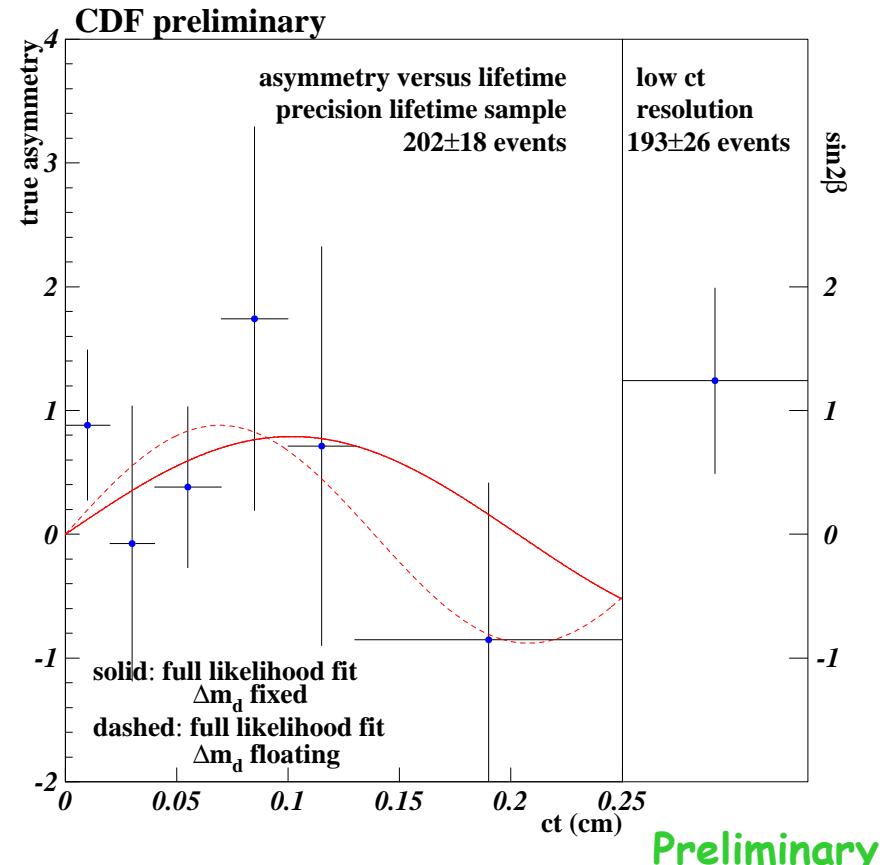
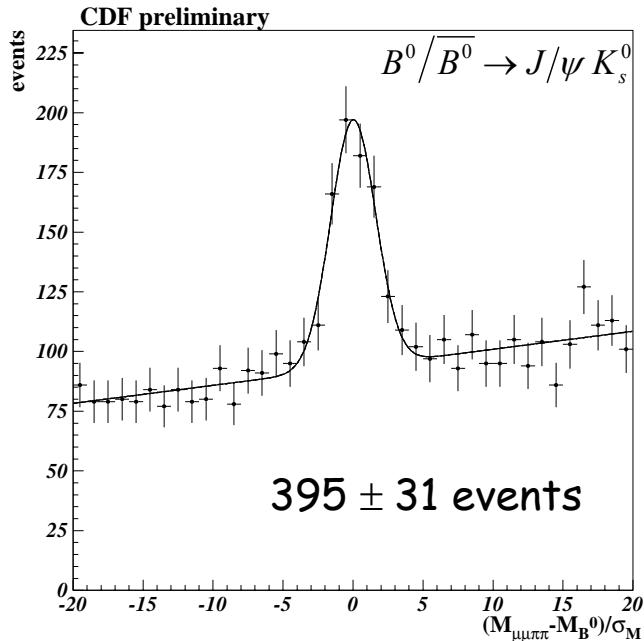
Preliminary

$$(28.0 \pm 3.0 \pm 2.6 \pm 1.0) \times 10^{-4}$$

$$= (28.0 \pm 4.1) \times 10^{-4} = \text{Re}(\varepsilon'/\varepsilon)$$

Direct CP violation firmly established
Rules out superweak model

Measurement of $\sin(2\beta)$ at CDF



Preliminary

$$\sin(2\beta) = 0.79 \pm 0.39_{\text{(stat)}} \pm 0.16_{\text{(syst)}}$$

First indication of CP violation in the B system, consistent with SM expectations

- Select events with two opposite charge μ and two pions
 - CP violation gives asymmetry in the decay rate of B^0 to $\overline{B^0}$
- $$\frac{N(\overline{B}^0 \rightarrow J/\psi K_s^0) - N(B^0 \rightarrow J/\psi K_s^0)}{N(\overline{B}^0 \rightarrow J/\psi K_s^0) + N(B^0 \rightarrow J/\psi K_s^0)} = \sin(2\beta) \sin \Delta m_t$$
- Flavor of B meson at the time of production identified by three different tagging algorithms calibrated with $B^\pm \rightarrow J/\psi K^\pm$ events.

Conclusions and Outlook

- New interesting results from the Tevatron on Jet, Photon and W/Z Physics
 - ➊ More details in parallel sessions
- New Constraints on Higgs Mass and measurements of CP violation
- Main Injector now being commissioned
 - ➋ New fixed target run in 1999
 - ➋ pbar p collider run to start in 2000 with $\sqrt{s} = 2.0$ TeV

Many new results still to come

Many thanks to Fermilab Collaborators
from DO, CDF, KTeV, E706, E791

Andrew Brandt, Daniel Elvira, Uli Heintz, Rob Snihur, Mike Strauss
Alex Akopian, Kerstin Borras, Frank Chlebana, Barry Wicklund
Peter Shawhan, Marek Zielinsky, Jeff Appel